

**Report on
Environmental Site Assessment of the Mission Bay Landfill
San Diego, California**

Submitted to:

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EXECUTIVE SUMMARY

MISSION BAY LANDFILL SITE ASSESSMENT REPORT

for

CITY of SAN DIEGO

The Mission Bay Landfill (Site) occupies much of a 113-acre site along the southeastern edge of Mission Bay, and ranges in thickness from approximately 5 to 22 feet. The Site operated as a municipal landfill from 1952 to 1959; it received hydraulic fill from dredging of Mission Bay from 1959 to 1969, and additional fill in about 1980. The fill material (soil) covering the landfill wastes is approximately 1.5 to 19.5 feet thick, and about 31% of the surface area is covered by asphalt and concrete (roads, parking lots, and pathways). The Site is located between the San Diego River and Mission Bay and the area was used as a landfill to infill wetlands during the construction of the river channel and Mission Bay Aquatic Park. As a result, brackish to saline water occurs within a portion of the base of the landfill. Water levels vary on a daily basis in response to tidal conditions within Mission Bay and the San Diego River. Seasonal flood events within the San Diego River also affect water levels within the landfill.

The waste at the Site is primarily municipal refuse, but portions of the waste are also reported to have originated at aerospace or other local industrial firms, and from the U.S. military. Overall, it is expected that some of these wastes contained industrial chemicals, including metals, solvents, and industrial process residues that today are regulated as hazardous waste. Groundwater, surface water, soil, and sediments are reported to contain detectable concentrations of contaminants of potential concern (COPCs). Notable COPCs include metals in soil and groundwater, and organic compounds in soil, landfill gas, and water. Landfill gases (e.g., methane, carbon dioxide, and hydrogen sulfide) also occur in the subsurface.

The City of San Diego's Mission Bay Landfill Technical Advisory Committee (TAC) was formed in August 2002 to review and assess the potential environmental impact of the Mission Bay Landfill. The TAC was convened by Councilmember Donna Frye and the City Environmental Services Department (ESD) to support the technical evaluation of the Mission Bay Landfill, and has overseen the work conducted by SCS Engineers (SCS). Monthly meetings have been, and continue to be, held to review, discuss, and provide input to the Site assessment reported herein and other associated matters. Members of TAC include public agency representatives, ESD staff responsible for the landfill, local citizens, and interested environmental professionals.

There were no state laws governing landfill closure requirements when the Mission Bay Landfill closed in 1959. The landfill is currently regulated by the City of San Diego Solid Waste Local Enforcement Agency (LEA) and the Regional Water Quality Control Board (RWQCB). There have been only two RWQCB orders applicable to the Site: Order 85-78, which established post-closure waste discharge requirements and monitoring requirements for the Site, and Order 97-11, which was deemed applicable because conditions at the Site

had changed considerably since Order 85-78 was issued. Order 97-11 required the City to comply with Monitoring and Reporting Program No. 97-11 and is currently in force. The present investigation of the Mission Bay Landfill was conducted by the City of San Diego independent of any regulatory agency order.

Review of previous Site investigations revealed factors that determined the approach specific to this landfill assessment, which was outlined in the draft workplan for the Mission Bay Landfill Site Assessment (Workplan). This review and critique of the previous environmental studies was conducted to assess the reliability/usability of the data set and the data gaps to be addressed by the proposed fieldwork. Aerial photographs, as well as prior maps, provided a wealth of information regarding the historical activities and development of the landfill. The acquisition and review of the available photos was conducted to assess pre-disposal conditions, disposal observations, limits of refuse or disposal areas, closure observations, cover soils, biosolids, and other similar issues of concern. The post-closure construction and surface activities also were reviewed.

The Workplan was distributed to the members of the TAC, the RWQCB, and the LEA for review and comment in early March 2004. The LEA in turn submitted the Workplan to the Office of Environmental Health Hazard Assessment (OEHHA) for review and comment. Comments on the Draft Workplan were received from a number of individuals and organizations by the requested deadline. Responses to these comments were prepared and compiled into an addendum that was submitted to the City, the TAC, and the agencies on April 27, 2004. One of the major changes that resulted from the comments was the intention to incorporate the Precautionary Principle into the risk assessment to the best of SCS's ability, given that we could find no evidence that it had been used in this type of application previously. The Draft Workplan was approved by the LEA and RWQCB prior to the commencement of the fieldwork.

This report includes a general project description and discussion of report components (Sections 1 and 2), summary of the findings of the initial document review (Sections 3 and 4), a description of the fieldwork and results (Section 5), a discussion of the results (Section 6), a revised Site Conceptual Model (Section 7), Human Health and Ecological Risk Assessments (Sections 8 and 9, respectively), conclusions (Section 10), and recommendations (Section 11).

The field investigation included implementation of the Workplan and interpretation of the resulting data. The fieldwork tasks performed for the site assessment included the following: a reconnaissance geophysical survey; installation of four monitoring wells and 18 soil borings; sampling of new and existing monitoring wells using a specific method for sampling and analysis for metals in brackish water; groundwater salinity profiles; soil vapor (landfill gas [LFG]) sampling; groundwater tidal studies and water level measurements; groundwater, surface and subsurface soil, and surficial sediment sampling; a biological survey to support an ecological health risk assessment; and a physical evaluation of the landfill cover. The fieldwork was implemented during the second half of 2004 and was followed by interpretation of the data and revision of the site conceptual model.

The human health and ecological risk assessments were conducted from late 2004 until mid-2005. Considerable input to, and expansion of, the proposed scope of the risk assessments was provided by the TAC based on technical memos prepared by SCS and subsequent presentations made at TAC meetings. In addition, as requested by the TAC during discussion of the submitted draft Workplan, the Precautionary Principle was applied to the Site assessment.

CONCLUSIONS

A brief summary of the main conclusions of the Site assessment follows:

Physical Extent

The vertical extent of the landfill has been defined during this assessment, and the delineation of the horizontal extent has been refined. The landfill area is estimated to be 113 acres, and the landfill volume is estimated from the isopach map to be 786,600 cubic yards. The average landfill thickness is 11.3 feet, and ranges from 0.5 to 22.5 feet.

Landfill Cover

The landfill is covered by 1.5 to 19.5 feet of soil. Approximately 31% of the surface cover is comprised of asphaltic concrete paving and hardscape. Soil testing has been conducted and the surficial soils do not have COPCs at significant concentrations.

Arsenic in soil, which is a naturally occurring element, is the main risk driver for the Site. However, all surface and shallow soil concentrations (less than 10 feet bgs) of arsenic at the Mission Bay Landfill were less than 10 mg/kg, below the Department of Toxic Substance Control (DTSC) arsenic background guideline of 11.3 mg/kg. The maximum soil concentration of arsenic detected was 60 mg/kg and another soil sample had a concentration of 45 mg/kg. However, both of these samples were detected at 10 feet bgs and therefore they pose a potential risk only to construction workers.

Chemical Composition

Part of the original scope of services itemized by the TAC was to determine/identify the average and maximum concentrations of any chemical contaminants within the boundaries of the Mission Bay Landfill to determine COPCs. A list of COPCs has been collated for each of the media at the landfill including soils, landfill gas, soil vapors, and groundwater. The ranges of concentrations for each of the COPCs in these media are provided in the report. The new COPCs that have been identified are bromodichloromethane, butane, chlorobenzene, chlorodifluoromethane, 1,2-dichlorobenzene, dichlorodifluoromethane, dichlorofluoromethane, ethane, ethanol, hexane, hydrogen sulfide, isopropylbenzene, pentane, pentachlorophenol, propane, 2-propanol, trichloroethene, and 1,2,4-trimethylbenzene.

Landfill Gas

Methane occurs within the landfill at concentrations ranging up to 57% (by volume), with an average concentration of about 20%. Although the methane generation rate will continue to decline as the site ages, it may not decline to negligible amounts for many years to come. The raw landfill gas (LFG) also contains some COPCs; benzene and vinyl chloride were detected. This is not unexpected – LFG at virtually all municipal landfills, regardless of whether they received systematic amounts of hazardous substances, contains low concentrations of benzene and vinyl chloride.

The continued generation of methane could pose a hazard if it can migrate laterally toward existing or future buildings on or near the Site. It is conventionally believed that methane can migrate up to 1,000 feet from the landfill boundary; however given the age and relatively shallow depth of Mission Bay Landfill, it is extremely unlikely that methane would migrate that far. Most importantly, existing concentrations of methane in the landfill gas do significantly exceed San Diego County's acceptable limits for safe construction. In addition, hydrogen sulfide concentrations in landfill gas may pose a risk to construction workers.

With respect to surface emissions, the combination of the low generation rate, the low quantities of COPCs in the raw gas, and the presence of the soil cover result in no significant emissions. Neither the surface sampling nor the Air Pollution Control District's ambient air testing resulted in the detection of any COPCs above background. There appears to be no significant human health risk and therefore no need for any type of gas control system at the Site.

Differential settlement can be expected as the organics within the refuse continue to decompose. Although the landfill is not very deep, and decomposition/settlement rates are well past peak, potential settlement cannot be ignored.

Groundwater Characterization

The hydraulic gradient is generally from the river to the bay, and groundwater is subject to tidal influences. There is a zone of groundwater approximately 2 to 8 feet thick with total dissolved solids (TDS) concentrations of 15,000 (river channel waters) to 35,000 mg/L (bay/ocean water) interpreted to overly a zone of fairly stagnant, hypersaline groundwater of over 40,000 mg/L TDS. Mixing and tidal influences are evident within the upper zone. There is a shorter path for groundwater across the landfill towards the boat basin, and the gradient is slightly higher across this area.

From the results of groundwater sampling in monitoring wells and soil borings, there appears to be very little in the way of volatile or semi-volatile organic compounds (VOCs or SVOCs) discharging from the landfill into the bay. The landfill cover is largely permeable and portions of the Site are irrigated; however, no significant decreases in groundwater salinities were observed related to irrigation or stormwater infiltration.

Solvents, Thallium, and Chromic Wastes

The general consensus of interested parties was that the most potentially problematic wastes placed in the landfill were chlorinated solvents and chromium. However, review of historical documentation indicated that the majority of the wastes described in these documents are primarily acids of various kinds, alkaline solution waste, cyanide wastes, magnesium wastes, and paint and oily wastes. There is only one reference to “combustible cleaning solvents (from dry cleaners).” Therefore, it is possible that the quantity of solvents placed in the landfill is not as great as has been discussed, because the majority of the industrial wastes appear to have been other chemicals as listed above. There is no evidence of highly elevated concentrations of chlorinated solvents such as trichloroethene or tetrachloroethene remaining in the landfill. If the documentation is incorrect and large quantities of these wastes were placed in the landfill, they likely have decomposed or degraded over time, which would be expected in such an anaerobic, methanogenic environment.

For a number of years, concerns have been voiced about the presence and concentrations of thallium in the landfill. Our review of previous thallium data in surface water, groundwater and sediment samples revealed a clear pattern of concentrations of thallium that were consistent within a sampling event, but not between sampling events, during the mid 1980’s and again in 1996. It is our interpretation that the most likely explanation of these patterns is that they represent the type of interference described by Chuck Budinger, a former member of the TAC, who researched the issue and concluded that certain analytical methods using light spectrometry can cause interference by other metals and lead to erroneous results, both for thallium or the other metals. Laboratory results for thallium in the current study showed no detectable concentrations of thallium in samples of surface or subsurface soils or sediment and a maximum concentration of thallium in groundwater that is lower than the public health goal.

Further, hexavalent chromium is not chemically stable under the geochemical conditions found in the landfill, which explains why it was not reported in groundwater samples, and was detected at very low concentrations in a few of the soil samples analyzed.

Human Health Risk Assessment

A baseline health risk assessment (HRA) was conducted for the Mission Bay Landfill to evaluate potential health risks of the landfill to the following potentially exposed receptor populations: adult and child recreational user, child swimmer, commercial worker, construction worker, and homeless or transient adult. The following exposure pathways were evaluated as appropriate depending on the receptor population: incidental soil ingestion, dermal contact with soil, inhalation of soil particulates in outdoor air, inhalation of volatiles in outdoor air, inhalation of volatiles in indoor air (vapor intrusion), dermal contact with surface water, and incidental ingestion of surface water. The HRA was prepared consistent with general risk assessment guidance from the state of California and U.S. EPA. More specific aspects of the risk assessment were reviewed and commented on by OEHHA. Health

risks associated with non-cancer risk, cancer risk, lead exposure, and hazard gases were evaluated.

Non-Cancer Risk

Non-cancer risk was evaluated based on calculation of the Hazard Index (HI), with an HI of 1 or less indicating no significant likelihood of adverse non-cancer health effects. HI values exceeded the negligible risk threshold of 1 for the construction worker population only. The HI value for the construction worker population was 4 with deep soil mercury concentrations, as documented by previous studies, contributing virtually all of the non-cancer risk. Direct contact with soil through incidental soil ingestion and dermal contact are the primary mechanisms of exposure to mercury. It should be noted that future construction on the site may be considered unlikely due to high concentrations of methane in landfill gas and continued differential settlement.

Lead

Lead risks were evaluated using the Leadsread 7 model approved by California regulatory agencies. Model results indicated that lead does not pose a health risk at the landfill for any of the receptor populations.

Hazard Gases

Risks associated with the hazard gases methane and hydrogen sulfide were evaluated based on direct measurement of soil gases, and for methane, ambient air. Methane concentrations in soil gas generally exceed building standards for safe construction established by the San Diego County Department of Planning and Land Use Building Department. Hydrogen sulfide concentrations in soil gas are below occupational exposure standards and therefore would be expected to be safe in ambient air due to dilution. However, pockets of high concentrations of hydrogen sulfide may be present in the landfill which could pose a hazard to construction workers since hydrogen sulfide is a fast-acting and highly toxic chemical.

Cancer Risk

The highest cumulative cancer risks were for the commercial worker and child recreational user with values of about 20 in 1,000,000. By comparison, the negligible cancer risk threshold for California risk assessments is 1 in 1,000,000. Cumulative cancer risks for all other receptor populations also exceed the 1 in 1,000,000 cancer risk threshold. However, it should be noted that virtually all of this increased cancer risk was due to arsenic present at values generally within the range of naturally occurring background levels. This is true for all other receptor populations as well. The most important exposure pathways contributing to the risk are incidental soil ingestion and dermal contact with soil. Two excessive concentrations of arsenic were detected in soils at 10 feet, indicating the presence of some arsenic contamination in

deep soils of the landfill. This arsenic primarily poses a risk to construction workers if excavation were to be conducted by unprotected workers at these locations.

Ecological Risk Assessment

A baseline ecological risk assessment (ERA), focusing on terrestrial ecological receptors, was conducted for the Mission Bay Landfill. The ERA was conducted in coordination with the Mission Bay Landfill TAC and prepared consistent with state of California guidance for ERAs at hazardous waste sites. Risks to the following representative ecological receptors were evaluated: northern harrier, California ground squirrel, mourning dove, and killdeer.

Exposures via the following pathways were evaluated: soil ingestion (all receptors), prey ingestion (harrier, killdeer), plant ingestion (ground squirrel, mourning dove), and landfill gas inhalation (ground squirrel only).

The total HI for each ecological receptor was less than 1, indicating no significant likelihood of adverse terrestrial ecological effects. It is expected that potential landfill effects on aquatic wildlife will be addressed via an aquatic or marine ecological risk assessment separate from the current scope of work.

RECOMMENDATIONS

Our recommendations for the Site are as follows:

- Expand the existing methane monitoring system at the landfill in collaboration with the LEA, particularly along the west and northwest boundary.
- Any future construction in the landfill would have to take into account the continued presence of methane and hydrogen sulfide, as well as differential settlement.
- Place additional soil cover in the eastern part of the landfill (35-acre parcel) to create an effective physical barrier. The cover is thinner in this area than in any other part of the landfill and, in places could easily be breached by animals digging or burrowing or by individuals attempting to scavenge metallic debris.
- After cover enhancements are complete, perform regular monthly surface emissions testing (integrated surface sampling) for one year to confirm results of this Assessment through four seasons.
- Conduct a Tier 2 marine or aquatic ecological risk assessment to examine in detail potential effects of landfill contaminants on aquatic life in Mission Bay.
- Continue the groundwater monitoring program as stipulated in the RWQCB Order. Reset the intake depths of the pumps in the existing monitoring well network so that the shallow “active” groundwater zone is sampled and conduct sampling using low-flow sampling methodologies.

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REPORT
on
MISSION BAY LANDFILL SITE ASSESSMENT
for
CITY of SAN DIEGO

1.0 SCOPE OF WORK/GENERAL PROJECT DESCRIPTION

1.1 Overview

The Mission Bay Landfill (Site) occupies much of a 113-acre site in former wetlands near the mouth of the San Diego River, along the southeastern edge of Mission Bay (Figure 1.1). The Site operated as a municipal landfill from 1952 to 1959; it received hydraulic fill from dredging of Mission Bay from 1959 to 1969, and additional fill in about 1980.

The landfill comprises an area of approximately 113 acres, and ranges in thickness from approximately 5 to 22 feet. The waste is covered with approximately 1.5 to 19.5 feet of soil and about 31% is covered by asphalt and concrete (roads, parking lots, and pathways). The Site is located between the San Diego River and Mission Bay and the area was used as a landfill to infill wetlands during the construction of the river channel and Mission Bay Aquatic Park. As a result, brackish to saline water occurs within a portion of the base of the landfill. Water levels vary on a daily basis in response to tidal conditions within Mission Bay and the San Diego River. Seasonal flood events within the San Diego River also affect water levels within the landfill.

The waste at the Site is primarily municipal refuse, but portions of the waste are also reported to have originated at aerospace or other local industrial firms, and from the U.S. military. Overall, it is expected that some of these wastes contained industrial chemicals, including metals, solvents, and industrial process residues that today are regulated as hazardous waste. Groundwater, surface water, soil, and sediments are reported to contain detectable concentrations of contaminants of potential concern (COPCs). Notable COPCs include metals in soil and groundwater (e.g., mercury, arsenic, lead, and chromium), and organic compounds in soil, landfill gas, and water (e.g., carbon tetrachloride, chloroform, bromoform, methylene chloride, diethyl ether, carbon disulfide, dichloroethene, vinyl chloride, phthalate compounds, and dichlorobenzene). MTBE (methyl tertiary butyl ether) and gasoline components (benzene, toluene, xylene) have also been detected in both surface water and groundwater. Landfill gases (e.g., methane, carbon dioxide, and hydrogen sulfide) also occur in the subsurface.

Both human health and ecological risk assessments have been conducted during this study to identify specific COPCs as potential “risk drivers.” The results of these analyses are summarized in Sections 8 and 9 of this Report.

Review of previous Site investigations revealed factors that determined the approach specific to this landfill assessment that was outlined in the workplan for the Mission Bay Landfill Site Assessment (Workplan), including the following:

- The landfill boundaries, operational history, and landfill contents had not been well documented and were uncertain. Historical data, primarily air photos and historical topographic maps as well as existing reports and documents, have been compiled and interpreted to develop an analysis of the landfill contents and to optimize the field investigation.
- The Site is adjacent to Mission Bay and the San Diego River. Groundwater levels vary daily and seasonally. Hydraulic influences include the tidally influenced Mission Bay and the San Diego River Channel, and flood events in the river. Varying salinities were reported for groundwater samples previously collected at the Site. Review of the data suggests that flow primarily occurs from the San Diego River across the Site toward Mission Bay in a northerly direction. Given the effect of tides in the bay and the river, and the potential for preferential flow paths such as the former San Diego River Channel that roughly bisects the Site, additional assessment of groundwater conditions was warranted.
- The need for remedial measures was based upon the results of the health risk assessment that evaluated potential exposure from COPC to humans and to the adjacent ecological systems.
- A variety of sources and transport mechanisms were identified to possibly exist at the Site. The results of the assessment performed by SCS Engineers (SCS) provided data to assess whether remedial measures are warranted.
- Given the highly visible and public nature of the landfill project, a focus on risk communication and public participation was necessary so that the results of this project were understood by, and acceptable to, the local community. The City of San Diego Mission Bay Landfill Technical Advisory Committee is the primary means for communication of the assessment process and the results in this Report as described in the following section.

Lastly, this assessment of the Mission Bay Landfill is one of many environmental assessments in the area. Mission Bay and the San Diego River channel are the endpoints of surface water drainages that have many potential sources of pollutants independent of the landfill. There are multiple ongoing and previously conducted studies. For example, because Mission Bay is considered to be an impaired water body under Section 303(d) of the Federal Clean Water Act (CWA), there are ongoing evaluations to determine the sources of coliform bacteria levels in the bay. The San Diego River channel is downstream of approximately 50 miles of the San Diego River and the watershed drains a significant portion of central San Diego County. Other studies include the City of San Diego Urban Runoff Management Program; the Mission Bay Citizen Water Quality Monitoring and Education Project and the Mission Bay Water and Sediment Testing Project conducted by the

University of San Diego in partnership with San Diego Coastkeeper; the Mission Bay Water Evaluation and Testing Study conducted by the University of California Berkeley School of Public Health; San Diego County Grand Jury review of two-stroke engines on Mission Bay; the Mission Bay Bacterial Source Identification project conducted by the City of San Diego for the State Water Resources Control Board (SWRCB); and numerous other local and regional scientific studies.

1.2 Relationship to the City of San Diego Mission Bay Landfill Technical Advisory Committee

The City of San Diego's Mission Bay Landfill Technical Advisory Committee (TAC) was formed in August 2002 to review and assess the potential environmental impact of the Mission Bay Landfill. The TAC is currently chaired by City Councilmember Donna Frye.

The TAC was convened by Councilmember Donna Frye and the City Environmental Services Department (ESD) to support the technical evaluation of the Mission Bay Landfill. Monthly meetings have been, and continue to be, held to review, discuss, and provide input to the Site assessment reported herein and other associated matters. Included on the TAC are public agency representatives, City of San Diego (ESD) staff responsible for the landfill and associated land, local citizens, and interested environmental professionals. The TAC has overseen the work conducted by SCS, which was approved by the City Council in July 2003 as the selected consultant, and is currently under contract with the City of San Diego to conduct the Mission Bay Landfill Site Assessment. The TAC participated in the consultant selection and in the review and approval of the work conducted at the Site. Please note that TAC discussions extend, at times, to areas outside of the Mission Bay Landfill. While some information has been obtained and analyzed by SCS in support of this Report for areas outside of the immediate landfill area, the scope of the Report as stated herein is limited to the Mission Bay Landfill. A list of TAC members is included in Appendix 1.3.

The following description of the TAC is from a web site supported by the City of San Diego for City Councilmember Donna Frye. The web site contains current versions of meeting notes and summary materials. It is available at:

http://genesis.sannet.gov/infospc/templates/cd6/mission_bay_landfill_committee.jsp

“The closed Mission Bay landfill was a receptacle for toxic materials for many years. The community has long expressed concern the landfill may be leaking since the landfill is not contained or lined. In August of 2002, Councilmember Frye and the Environmental Services Department began a new investigation into the current conditions at the landfill. The goal of the investigation was to determine the environmental and public health issues surrounding the Site.

In order to help evaluate and advise the City during this investigation, Councilmember Frye convened the Mission Bay Technical Advisory Committee. This oversight committee is made up of technical experts and community members interested in completing a Site assessment and determining appropriate clean up measures for the landfill.”

1.3 Workplan and Report Review Process

The Draft Workplan was distributed to the members of the TAC, the Regional Water Quality Control Board (RWQCB), and the City of San Diego Local Enforcement Agency (LEA) for review and comment in early March 2004. The LEA in turn submitted the Workplan to the Office of Environmental Health Hazard Assessment (OEHHA) for review and comment. A request was made for comments to be received as soon as possible and prior to the March 25th TAC meeting so that they could be discussed.

Comments on the Draft Workplan were received from a number of individuals and organizations by the requested deadline. Those submitting responses included: The City of San Diego Local Enforcement Agency (LEA); County of San Diego Air Pollution Control District (APCD); the San Diego Chapter of the Sierra Club; Jeoffrey Gordon, MD; Chuck Budinger, PG; Benjamin Leaf; David Kennedy, DDS; Kathleen Blavatt (Citizens for Safe Drinking Water); James Miller (Mission Bay Park Toxic Cleanup); and Frank Gormlie (Ocean Beach Planning Board).

Responses to these comments were prepared and compiled into an addendum that was submitted to the City, the TAC, and the agencies on April 27, 2004. In general, there were two areas of concern. The first was historical, and in many cases additional details or events associated with the Site were requested. The second area was specific to the proposed sampling plan and data analysis. One of the major changes that resulted from the comments was the intention to incorporate the Precautionary Principle into the risk assessment to the best of SCS's ability, given that we could find no evidence that it had been used in this type of application previously. In addition, analysis for hexavalent chromium was included for a subset of soil samples and for all the groundwater samples that were collected.

In May 2004, letters were received from the RWQCB and OEHHA with comments on the Draft Workplan. These comments were discussed with City personnel and responses to them were incorporated into the fieldwork. Written responses were subsequently drafted to the two agencies. Ongoing correspondence resulted with OEHHA in which various issues relating to the risk assessment were addressed. A copy of this correspondence is provided in Appendix 1.2.

The Draft Workplan was approved by the LEA and RWQCB prior to the commencement of the fieldwork.

1.4 Scope of Services

The scope of services for this project was described in a request from the City of San Diego for consulting services (Request for Proposal [RFP]). The objectives of this Report, as stated in the RFP, include the following:

1. Determine the horizontal and vertical extent of the Mission Bay Landfill to determine where COPC [Chemical of Potential Concern] may have been disposed of.
2. Determine/identify the average and maximum concentrations of any chemical contaminants and distribution within the boundaries of the Mission Bay Landfill to determine COPC.
3. Compile and compare previous analytical results to ensure that all COPC are included in any health risk assessment.
4. Determine the fate and transport of COPC that may have been disposed of during the active life of the Mission Bay Landfill.
5. Determine any potential ecologic or human health impact(s) of the COPC by exposure to the soil, sediments, groundwater, surrounding surface water, or air.
6. Evaluate any potential ecological or human health impacts(s) to determine if remediation is warranted.
7. Present potential alternative methods if remediation is warranted.

These objectives were addressed in five project tasks. These included:

- | | |
|---------|--|
| TASK 1. | Preliminary Review, Forensic Analysis, and Preparation of Field Investigation Workplan |
| TASK 2. | Field Investigation |
| TASK 3. | Site Conceptual Model, Human Health and Ecological Risk Assessment |
| TASK 4. | Remedial Feasibility Study |
| TASK 5. | Final Report |

A sixth task, Preparation and Participation in TAC Meetings, also has been, and continues to be, conducted for this project by SCS.

Specifically, Tasks 1 and 2 addressed listed objectives 1, 2, and 3 with respect to determining the extent and magnitude of COPC and compiling sufficient data for completion of a human health and ecological risk assessment. The emphasis of Task 1 was to critically examine the work conducted to date at the Mission Bay Landfill, and to identify additional fieldwork and analysis that were needed to address the overall project objectives. This additional fieldwork and analyses in Task 2 were designed to further address the same objectives 1, 2, and 3.

Task 3 addresses listed objectives 4, 5, and 6 as they pertain to the assessment of human health impacts and ecological risks for exposed populations, including fate and transport of COPC in the environment. Task 4 addresses objective 7 as it relates to the risk-based evaluation of potential remedial strategies.

Please refer to Section 2 of this Report for additional description of how these tasks have been implemented. At the request of TAC members, a list of SCS Engineers personnel involved in the assessment has been included in Appendix 1.4.

1.5 Regulatory Setting

There were no state laws governing landfill closure requirements when the Mission Bay Landfill closed in 1959. The first reference to regulatory agency requirements specific to the landfill was in 1984, as a result of interest in building a hotel on the Site. Following is a listing of the regulatory requirements and decisions applicable to the Site, along with other related information. There have been only two Regional Water Quality Control Board (RWQCB) orders applicable to the Site: Orders 85-78 and 97-11. Order 97-11 is currently in force. A copy of Order 97-11 is included as Appendix 1.1.

- **1958:** Regional Board Resolution No. 58-R15 was approved, and regarded proposed waste disposal operations at the Omar Rendering Facility, which likely took wastes that had been going to Mission Bay Landfill.
- **1972:** Prior to the California Code of Regulations (CCR), state requirements regulating waste discharges to land were located in the California Administrative Code (CAC). Earliest available guidance documentation from the SWRCB (Franks, A.L., 1972, "Waste Discharge Requirements for Non-sewerable Waste Disposal to Land: Disposal Site Design, Operation, and Closure Information," pp. 31-35, and Appendix I, California SWRCB) allowed facilities to accept Group 1 (hazardous/toxic), Group 2, and Group 3 wastes for disposal.
- **Sept. 1977:** The Second Basic Agreement for Public Health Services to Be Furnished by the County to the City of San Diego. There is no specific mention of Mission Bay Landfill.
- **Early 1980s:** The California Department of Toxic Substance Control (DTSC) and other agencies investigated the Site for toxic and hazardous waste disposal became involved; this was related to interest in building a hotel on the Site.
- **September 1985:** *RWQCB Order 85-78* established post-closure waste discharge requirements and monitoring requirements for the Site. "Order 85-78: Waste Discharge Requirements for the Site Closure of the City of San Diego Mission Bay Landfill, San Diego County."
- **1985:** San Diego County Environmental Health Services Division (EHS) (now called the Department of Environmental Health or DEH) was designated as the Lead Enforcement Agency for Mission Bay Landfill.
- **Jan. 1987:** DTSC (formerly known as Department of Health Services, Toxic Substances Control Division) entered into agreement with the City, giving responsibility over the landfill to the City. DTSC has not had any formal regulatory involvement with the landfill (September 5, 2003 letter from DTSC to California Coastal Commission [CCC]).
- **July 28, 1987:** The APCD issued a letter to the City of San Diego in which they granted an exemption from surface emissions monitoring.
- **LEA authority** (as cited in May 23, 1995 letter regarding concern that the South Shores Phase III Project may jeopardize landfill integrity, and requiring that a post-closure land use plan be developed):

- Pursuant to the California Public Resources Code (PRC), Section 44105(b), and the CCR, Section 18083, the County of San Diego Department of Environmental Health (DEH), acted as the LEA for solid waste issues in the City of San Diego.
 - Article 7.8, Title 14, CCR (14 CCR) establishes standards and minimum requirements for proper closure, post-closure maintenance and ultimate reuse of solid waste disposal sites to assure that public health and safety and the environment are protected from pollution due to the disposal of solid waste. Regulations contained in this article apply to new post-closure activities that may jeopardize the integrity of previously closed sites or pose a potential threat to public health and safety or the environment.
- **May 23, 1995:** Notice of Exemption- from County DEH to County Recorder: Official Notice for compliance with statutory and regulatory requirements at the closed Mission Bay Landfill Solid Waste facility – categorical exemption from the California Environmental Quality Act (CEQA) as an enforcement action by regulatory agency (Section 15321).
- **April 1997:** *RWQCB Order 97-11* was deemed applicable because conditions at the Site had changed considerably since Order 85-78 was issued. The primary change in Site conditions was the construction of the “South Shores” portion of Mission Bay Park. Order 97-11 required the City of San Diego to comply with Monitoring and Reporting Program No. 97-11.
- **Nov. 19, 1997:** City of San Diego certified by the California Integrated Waste Management Board (CIWMB) to be the Solid Waste Local Enforcement Agency for the implementation of State Minimum Standards of facilities within the City of San Diego (to enforce state solid waste laws and regulations at solid waste sites, including closed landfills). Prior to Nov. 19 this LEA function was carried out by County of San Diego DEH.
- **February 5, 2003:** The Regional Board adopted a name change for the Order (Addendum No. 3 to Order No. 97-11) currently used to regulate the Mission Bay Landfill. The current title of the Order is as follows: “*General Waste Discharge Requirements for Post-Closure Maintenance of Inactive Landfills Containing Hazardous and Nonhazardous Wastes Within the San Diego Region.*” This is to provide recognition that the Mission Bay Landfill is likely to contain hazardous materials/wastes (per TAC request). (August 4, 2003 letter)
- **2003:** The Regional Board currently regulates the Mission Bay Landfill pursuant to waste discharge requirements (WDRs) issued to the City of San Diego as Order 97-11 (and addenda thereto). The Order currently uses requirements of CCR Title 23, Chapter 15 (waste discharge to land) and CCR Title 27, Section 21190 (post-closure land use) to prescribe post-closure maintenance and monitoring requirements for the Mission Bay Landfill.

Various Regulatory Information:

As previously stated, both the RWQCB and the City of San Diego Local Enforcement Agency (LEA) participated in the review of the Workplan and representatives from these agencies have attended the majority of the TAC meetings.

- The LEA enforces the following:
 - State Law: Public Resources Code (PRC), Division 30. Waste Management.
 - State Regulation: Title 27 Environmental Protection, CCR, Division 2. Solid Waste (27 CCR); Title 14, Natural Resources, CCR, Division 7, California Integrated Waste Management Board (CIWMB) (14 CCR).

Mission Bay Landfill is defined under state law as a disposal site and under state regulation as a closed site.

- 2001 – RWQCB and CIWMB have requirements for inactive landfills. The City LEA enforces the CIWMB regulations.
- The intent of the SWRCB, regarding application of current regulations to older units, is expressed in CCR Title 23, Section 2510(g) and CCR Title 27, Section 20080(g). These regulations specifically exempt facilities that were closed, abandoned, or inactive (CAI), prior to 1984, from meeting any but the new monitoring requirements. The decision on whether to apply the revised monitoring requirements is at the discretion of the appropriate Regional Board. (August 4, 2003 letter)
- The City of San Diego is an operator and owner of active and closed solid waste disposal sites, including the Mission Bay Landfill.
- RWQCB classifies the landfill as a Class III municipal solid waste (MSW) landfill. Current regulations (SWRCB) do not classify waste management units based upon the nature of the waste during their operational history. They are classified instead by a combination of the siting criteria and containment system criteria they can meet at the time of permitting for waste management/disposal operations. (August 4, 2003 letter).

1.6 ARARs/TBCs: Identification of Applicable or Relevant and Appropriate Requirements (ARARs)

One way to try to address the overall regulatory requirements for a site assessment is in the context of Applicable or Relevant and Appropriate Requirements (ARARs). A second category of “To Be Considered” or TBCs is also used to address potential requirements for a site. ARARs and TBCs are the subject of this section.

Multiple environmental regulatory agencies exist in California, and some of the state regulations have been derived from, or are in compliance with, federal regulations. Over time regulatory guidance and prior cases have shaped what may be required at a particular site or type of site. This has led to a combination of multiple overlapping agencies, each with their own interpretation of local, state, and federal regulations. Some of requirements may be derived from laws and others from guidance documents (or even staff-issued memoranda) that technically are not legal requirements.

This investigation of the Mission Bay Landfill was conducted by the City of San Diego independent of any regulatory agency order. Although not required, as the work was not conducted in the context of a federal “Superfund” site under Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (as amended by the Superfund Amendments and Reauthorization Act of 1986 [SARA]), the overall regulatory framework for the site assessment can be explained in terms of ARARs. The “Superfund” approach taken here provides for federal guidance associated with the determination of human health and ecological health risk. The risk assessment approach provides an additional measure of the site that is not embodied, for example, in a strict interpretation of water quality objectives.

1.6.1 Introduction

Section 121 of SARA specifies that on-site actions should attain legally applicable or relevant and appropriate standards, requirements, criteria, or limitations. These include “any standard, requirement, criteria, or limitation under any federal environmental law” and “any promulgated standard, requirement, criteria, or limitation under a state environmental or facility siting law that is more stringent than any federal standard, requirement, criteria, or limitation” if it has been approved, authorized, or delegated by the Administrator and has been identified to the EPA by the state “in a timely manner.” Applicable or relevant and appropriate requirements, criteria, advisories, and guidance at the local level, although not requiring evaluation under SARA, were also considered.

The main distinction to be made for this project is that “applicability” is a legal and jurisdictional determination, while the determination of “relevant and appropriate” relies on professional judgment, considering environmental and technical factors at a given site. The determination whether a regulation is relevant and appropriate is more discretionary. A requirement may be “relevant,” in that it covers situations similar to those at the Site, but may not be “appropriate” and, therefore, may not be well suited to the Site.

To-Be-Considered (TBC) requirements are non-issued advisories, e.g., reference doses or potency factors, criteria, and guidance issued by federal and state governments. TBC requirements do not have the status of ARARs. However, Section 300.400(g)(3) of the National Contingency Plan specifies that TBC requirements shall be identified as appropriate where ARARs do not exist or where ARARs have been determined to be insufficient to ensure protection of human health and the environment for a particular release. TBC requirements may be considered to determine the necessary level of cleanup for protection of health or the environment.

The location of the Site determines how many of the potential ARARs are to be interpreted. Principal concerns for this Site are the evaluation of groundwater and surface water quality, bay sediment quality, and air quality related to the migration of landfill gas or toxic gases that may be present within the landfill. It has been established that groundwater beneath the Site is in a location of high total dissolved

solids (TDS) waters and thus is considered to have “non-beneficial” uses specific to drinking water as described in the San Diego RWQCB Basin Plan. For surface water, the waters of Mission Bay have salinities in excess of 25,000 milligrams per liter (mg/L) TDS. Therefore, salt water criteria are most directly applicable to the selection of the surface water ARARs.

However, the Site is also adjacent to the mouth of the San Diego River. At this location, the quality of the river water is strongly influenced by ocean tides and is likely to be brackish as a result. The San Diego RWQCB Basin Plan designates the mouth of the San Diego River as “coastal waters.” Beneficial uses of coastal waters do not include drinking water. The relevance of fresh water criteria to coastal waters has yet to be determined.

1.6.2 Types of ARARs

There are three general types of ARARS. These include chemical-specific, location-specific, and action-specific.

(1) Chemical-Specific ARARs are typically health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, are expressed as numerical values that represent cleanup standards (i.e., the acceptable concentration of a chemical at the site). Examples of chemical-specific ARARs include non-zero maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs) established under the Safe Drinking Water Act, and federal water quality criteria (FWQC) established under the Clean Water Act. As a general rule, if more than one chemical-specific ARAR exists for a particular contaminant, the most stringent should be applied.

(2) Location-Specific ARARs are restrictions on the concentration of hazardous substances or the conduct of activities in environmentally sensitive areas. Relevant examples of restrictions on the conduct of activities in environmentally sensitive areas include floodplains, wetlands, and locations where endangered species or historically significant cultural resources are present.

(3) Action-Specific ARARs are usually technology- or activity-based requirements or limitations on actions or conditions taken with respect to specific hazardous substances. An example for this project is the CIWMB requirements for post-closure landfill care. Action-specific ARARs do not determine remedial alternatives; rather, they indicate how a selected alternative must be achieved. The Resource Conservation and Recovery Act (RCRA) and the Clean Water Act provide the majority of action-specific ARARs.

1.6.2.1 Chemical-Specific ARARs

The San Diego RWQCB Basin Plan (Water Quality Control Plan for the San Diego Basin (9), RWQCB 1994) establishes beneficial uses and water quality objectives

(WQOs) for surface waters and groundwater in the San Diego area. However, the numerical, chemical-specific WQOs given in Tables 3-2 and 3-3 of the Basin Plan are specific for inland surface waters and groundwater and thus may not be applicable to the coastal waters of Mission Bay or the mouth of the San Diego River. Similarly, MCLs and Primary and Secondary Drinking Water Standards are generally applicable to potential municipal water supply sources, a designation that does not apply to the bay or the mouth of the tidally-influenced San Diego River.

Chemical-specific ARARs in the Basin Plan that would apply to the coastal surface waters around the landfill include the following:

- The discharge of wastes shall not cause concentrations of un-ionized ammonia to exceed 0.025 milligrams per liter (mg/L) (as N).
- Dissolved oxygen levels shall not be less than 5.0 mg/L in inland surface waters with designated MAR or WARM beneficial uses or less than 6.0 mg/L in waters with designated COLD beneficial uses. The annual mean dissolved oxygen concentration shall not be less than 7 mg/L more than 10 percent of the time.
- In bays and estuaries the pH shall not be depressed below 7.0 nor raised above 9.0.
- Waters shall not contain oils, greases, waxes, or other materials in concentrations which result in a visible film or coating on the surface of the water or on objects in the waste, or which cause nuisance or which otherwise adversely affect beneficial uses.
- No individual pesticide or combination of pesticides shall be present in the water column, sediments or biota at concentrations that adversely affect beneficial uses. Pesticides shall not be present at levels which will bioaccumulate in aquatic organisms to levels which are harmful to human health, wildlife or aquatic organisms.

Based upon the specific site conditions, the chemical-specific groundwater and surface water ARARs are generally restricted to ecologically-based numerical criteria for salt water as detailed in the RWQCB Basin Plan. Exceedances of these criteria would be relevant if it could be established that leachate or runoff from the Mission Bay Landfill was responsible for impacts to the bay.

The SWRCB is currently in the process of developing sediment quality objectives for enclosed bays and estuaries in California. These objectives would be relevant, again to the extent that it can be established that the Mission Bay Landfill has impacted bay sediments.

SWRCB Resolution No. 68-16 reflects the state's policies for "maintaining high quality of waters in California." Commonly referred to as the anti-degradation policy, this resolution applies to waste discharges that might affect the existing quality of the water into which it is discharged, and thus affect its beneficial use.

SWRCB Resolution 92-49 establishes policies and procedures for the oversight of investigations and cleanup activities resulting from discharges that affect or threaten water quality. This policy authorizes regional boards to oversee cleanup activities and to require complete cleanup of all waste discharged. These policies are ARARs that would apply if it were established that leachate, gas, or surface runoff from the landfill had impacted or threatened either Mission Bay or the San Diego River.

The two resolutions referred to above also indicate that background conditions should be a long-term remediation goal. Because of the complexities of the Mission Bay and San Diego River Channel hydrology and the number of other potential sources of waste discharges to the bay and river, establishing background conditions may not be practical.

1.6.2.2 *Location-Specific ARARs*

On-site operations must take into account location-specific ARARs. These would include the obtaining of any local permits/authorization from San Diego City and County and the RWQCB, public notification requirements, San Diego Air Pollution Control District (SDAPCD) permits/requirements specific to this area, compliance with the CEQA, compliance with relevant portions of Titles 22 and 27 of the CCR, and local ordinances pertaining to noise, traffic, and other nuisances.

If remedial action is warranted, or if COPC are left in-place in concentrations which present an unacceptable risk or potential risk, the following location-specific ARARs may apply:

- Long-term operation and maintenance (O&M) of the contaminated area as a waste impoundment (22 CCR).
- Groundwater and/or vadose zone monitoring (22 CCR).
- Deed restriction (San Diego City/County requirements).
- Use restriction (San Diego City/County requirements).
- Notification requirements for property transactions/transfers (22 CCR).
- Continued financial responsibility (23 CCR).

The location of the Site may place other constraints on future Site activities.

1.6.2.3 *Action-Specific ARARs*

Most action-specific ARARs address treatment, transportation, and disposal of hazardous waste. The following text addresses action-specific ARARs that may be associated with possible remedial actions.

If it becomes necessary in the future to collect and dispose of landfill leachate, whether treated or untreated, the general pretreatment requirements of the Federal Clean Water Act would apply. Discharge of treated or untreated leachate to a

navigable waterway (e.g., Mission Bay) would be regulated under the National Pollutant Discharge Elimination System (NPDES); compliance with surface water discharge standards is enforced by the RWQCB.

Other chemically-specific numerical standards may or may not be relevant to the Site, depending on the direction of future activities. For instance, RCRA Toxicity Characteristic Leaching Procedure (TCLP) and California Total Threshold Limit Concentrations (TTLC)/ Soluble Threshold Limit Concentration (STLC) values are not applicable as clean-up standards nor do they apply directly to in-place soils. However, if any soils, sediments, or refuse are excavated from the Site in the future, these values will be used to determine whether the excavated material is hazardous for the purposes of disposal.

Similarly, U.S. EPA Region IX Preliminary Remediation Goals (PRGs) provide useful guidance for determining when remediation might be necessary. The PRGs were published in United States Environmental Protection Agency memo, *Region 9 Preliminary Remediation Goals (PRGs) 2002 Update*, dated November 1, 2002 revised December 28, 2004.

However, PRGs do not apply to the refuse and other waste materials in the landfill; rather they are intended to apply to “environmental media (e.g., soil, air, and water).” The PRGs would apply if there was evidence that the landfill had impacted soils, air, and/or water. PRGs are risk-based values that assume certain direct exposures (i.e., ingestion, dermal contact, an inhalation). If the pathways are not present, the PRGs may not apply. Finally, as described by the U.S. EPA in the PRG document, “the PRGs are specifically not intended as a (1) stand-alone decision-making tool, (2) as a substitute for EPA guidance for preparing baseline risk assessments, (3) a source of site-specific cleanup levels, or (4) a rule to determine if a waste is hazardous under RCRA.” According to the U.S. EPA, the “PRG table combines current EPA toxicity values with ‘standard’ exposure factors to estimate contaminant concentrations in environmental media (soil, air and water) that are protective of humans, including sensitive groups, over a lifetime.”

In addition to the PRGs, the California Human Health Screening Levels (CHHSLs) developed by the California Environmental Protection Agency (Cal EPA) can also be used to assess when remediation might be necessary. According to the Cal EPA, “the CHHSLs were developed by the Office of Environmental Health Hazard Assessment (OEHHA) on behalf of Cal EPA, and....were developed using standard exposure assumptions and chemical toxicity values published by the U.S. EPA and Cal/EPA.” A guidance document (California Environmental Protection Agency, *Use of California Human Health Screening Levels (CHHSLs) in Evaluation of Contaminated Properties*, January 2005.), regarding the use of CHHSLs, has been developed by the Cal EPA. According to this document, “CHHSLs are concentrations of 54 hazardous chemicals in soil or soil gas that the Cal EPA considers to be below thresholds of concern for risks to human health. The CHHSLs can be used to screen sites for potential human health concerns where releases of hazardous chemicals to soils have

occurred. Under most circumstances, and within the limitations described in this document, the presence of a chemical in soil, soil gas, or indoor air at concentrations below the corresponding CHHSLs can be assumed to not pose a significant health risk to people who may live (residential CHHSLs) or work (commercial/industrial CHHSLs) at the Site. The presence of a chemical at concentrations in excess of a CHHSL does not indicate that adverse impacts to human health are occurring or will occur but suggests that further evaluation of potential human health concerns is warranted.”

Both the PRGs and the CHHSLs are intended to provide preliminary risk screening and soil remediation goals for properties with soil contamination.

Any landfill-related actions fall within the guidelines and regulations promulgated by the CIWMB and SWRCB under 27 CCR and guidance issued by the CIWMB to the LEAs. These ARARs will be incorporated into documentation to be submitted to the LEA and/or RWQCB for review and approval prior to the implementation of such action. Among the issues addressed by CIWMB and/or RWQCB for the action-specific ARARS are storm water controls, leachate and landfill gas monitoring, surface caps and grading, and similar requirements designed to minimize the potential environmental impact of the landfill. Once completed, there will be long-term maintenance requirements associated with the soil cap, soil cap vegetation and stabilization, and storm water controls.

The San Diego County APCD also has rules that apply to landfills and activities conducted on landfills. For instance, Rule 59 states that:

- the concentration of organic compounds must not exceed 500 parts per million by volume (ppmv) expressed as methane at any point measured immediately above the surface of the landfill;
- the concentration of any toxic air contaminant emitted to the atmosphere from any point measured immediately above the surface of the landfill and from any landfill gas collection, energy recovery, gas purification and/or disposal system must not exceed the threshold level established for that toxic air contaminant by the California Air Resources Board (CARB),
- there are no detectable emissions of any toxic air contaminant for which the CARB has not specified a threshold exposure level because there is no known level below which no significant adverse health effects are anticipated;
- and the concentration of any toxic air contaminant emitted to the atmosphere from any point measured immediately above the surface of the landfill and from any landfill gas collection, energy recovery, gas purification and/or disposal system must not exceed either the Threshold Limit Value established for that toxic air contaminant by the American Conference of Governmental Industrial Hygienists or any concentration that poses an unacceptable health risk to human beings as determined by the Air Pollution Control Officer after consultation with the appropriate local, state, or federal governmental health agency.

Under Rule 1200, the Air Pollution Control Officer can deny operations permits if proposed activities might increase emissions of listed toxic air contaminants, unless specific requirements are met. Rule 1210 mandates public notification if a risk assessment indicates that there are potential public health risks above levels specified in the rule. In addition, if the potential public health risks are equal to or greater than the specified risk mitigation levels, a stationary source toxic air contaminant risk reduction audit and plan will be required.

In the event that material is excavated from the Site and determined to be hazardous waste for the purposes of disposal, transportation of the hazardous waste will be regulated by the Department of Transportation (DOT). Hazardous waste haulers must be licensed by DTSC and the EPA. Disposal of any excavated material will be governed by CCR 22, Division 4.5, Chapters 11 and 12, which provide minimum standards for the management of hazardous waste.

In addition to the ARARs specified above, there are a variety of other guidances, background documents, and reports which support each of the above regulatory programs. These guidances do not carry the force of actual ARARs; however, they could become ARARs based on project conditions. Therefore these guidances are “to-be-considered (TBC).”

1.7 Acknowledgments

This Report represents a lengthy collaboration between the Technical Advisory Committee, the City of San Diego Environmental Services Division, and SCS Engineers. SCS is particularly grateful for the contributions of the City staff including Ray Purtee, Sylvia Castillo, Steven Fontana, and Chris Gonaver; all voting and non-voting members of the TAC (and their alternates) including Dr. Gordon, Dr. Kennedy, Dr. Huntley, Barry Pulver, Judy Swink, OBGO, Mission Bay Boat and Ski Club, San Diego Baykeeper, Ocean Beach Planning Board, Sierra Club, Jenny Quintana (SDSU), Robert Tukey (UCSD), and chairperson City Councilmember Donna Frye and her staff; interested and concerned citizens and other observers who attended TAC meetings on a regular basis; regulatory agency personnel including Rebecca Lafreniere (LEA) and Brian McDaniel (RWQCB), who also attended TAC meetings frequently; and the APCD for conducting the ambient air monitoring.

2.0 SITE ASSESSMENT REPORT COMPONENTS

2.1 *Site Assessment Workplan*

The site assessment workplan (Workplan) was based upon a review of previous data, recently conducted historical research, and evaluation of the usefulness of the previous data. These elements were then used to identify data gaps and to develop a field investigation draft workplan. The Workplan was based upon the previously described scope of services (Section 1.4) and was submitted to the TAC and local oversight regulatory agencies for review and input.

Relevant to this Report, the Workplan included the following sections:

2.1.1 WP Section 2. Technical Background

An annotated bibliography was compiled that documents the reports and correspondence obtained from various sources (Appendix 2.1). The previous data were compiled and reviewed. Portions of the data were used in a quantitative manner where supporting information was available and the data were properly collected or analyzed. An initial summary was presented that was revised and expanded subsequent to the collection of new Site data.

2.1.2 WP Section 3. Review of Known Conditions/Site Conceptual Model

An extensive amount of historical research was conducted, much of which was based upon review of historical photographs and engineering maps that describe the development of Mission Bay and the Mission Bay Landfill. The final version of the historical review is included in Section 3 of this Report. The compilation of analytical data previously collected at the Site was reviewed and interpreted to support the additional assessment activities. Section 3 of the Workplan also included a preliminary Site Conceptual Model (SCM), to provide the reader with an overall understanding of the general landfill characteristics, the geologic and hydrogeologic nature of the Site, and the distribution of contaminants in soil, sediment, groundwater, and soil vapor. The SCM was used to identify the potential pathways and receptors for potential contaminant release scenarios from the landfill. The importance of the SCM is that it established the basis for assessing the risks to potential receptors and the framework for the investigation and remedial effort to be conducted at the Site. A revised SCM is presented in Section 7 of this Report.

2.1.3 WP Section 4. Proposed SCS Fieldwork

A multi-disciplinary approach was proposed to evaluate current conditions at the Site. Some tasks such as evaluation of the tidal influences upon groundwater and the collection of soil vapor data from within the landfill had not been conducted at the Site prior to the SCS site assessment. The primary goal of the fieldwork was to

expand the previous collection of physical and chemical data to support human health and ecological risk assessments.

The fieldwork generally followed the protocols and guidance established by the County of San Diego in the 2004 Site Assessment and Mitigation (SAM) Manual. It is available online at

http://www.sdcountry.ca.gov/deh/lwq/sam/manual_guidelines.html

2.1.4 WP Section 5. Site Conceptual Model Revision Process

Following collection of new data, the initial assessment of Site conditions was revised in the context of a site conceptual model. The potential exposure of humans and ecological receptors was examined in a quantitative manner, and the relative understanding of Site conditions was further developed.

2.1.5 WP Section 6. Health Risk Assessment Outline

The risk assessments evaluate the potential impact of hazardous substances known to occur at the Site. Potential risks to both human and ecological receptors were evaluated and reasonable maximum exposures to COPC were assessed. The potential ecological receptors were identified by a field biology survey as described in Section 5.6 of this Report.

2.2 Fieldwork (Section 5)

Included among the fieldwork tasks performed for the site assessment, described in Section 5, are the following: a reconnaissance geophysical survey; installation of four monitoring wells¹; sampling of new and existing monitoring wells; groundwater salinity profiles; soil vapor (landfill gas [LFG]) sampling; soil sampling (adjacent to, above, and below the refuse); groundwater tidal studies and water level measurements; groundwater, surface soil, and surficial sediment sampling; a biological survey to support an ecological health risk assessment; and a physical evaluation of the landfill cover and cap. Table 5.2 provides a summary of the tasks.

A portion of the fieldwork required an assessment of existing biological conditions relative to the ecological risk assessment. A qualified biologist knowledgeable in local conditions of the San Diego River Estuary and Mission Bay was subcontracted by SCS.

Applicable site investigation standards and guidance have been cited, as appropriate. The scope of the field investigation was based, in part, on the activities conducted during Task 1. The field investigation included implementation of the Workplan produced in Task 1 and interpretation of the resulting data.

¹ The term monitoring well(s) as used in this report refers to groundwater monitoring well(s).

Progress reports were provided to the TAC as data was collected and compiled and could be readily communicated. Pursuant to a request made during a TAC meeting, a technical subcommittee was created so that members of the TAC (Barry Pulver and Dr. David Huntley) could review preliminary results from the field study and be involved in decisions regarding changes to the scope of the Workplan. Several meetings were held at the SCS offices during which the subcommittee of the TAC reviewed data from various parts of the field study and gave input on changes to the locations of the new wells, on the need for (and the preferred locations of) additional soil borings, and on the need for an additional day of soil vapor sampling subsequent to the landfill gas survey. In addition, the proposed relocation of two drive points was communicated to the subcommittee by email.

2.3 *Historical Review, Data Compilation, and Site Assessment Findings (Sections 3 and 6)*

Air photo interpretation, as well as review of prior maps, was used to assess whether the landfill boundaries had been adequately characterized. Since the boundaries could not be accurately determined in certain areas, further field-based assessment was deemed necessary.

Aerial photographs provided a wealth of information regarding the historical activities of the landfill. The acquisition and review of the available photos was conducted to assess pre-disposal conditions, disposal observations, limits of refuse/disposal areas, closure observations, cover soils, biosolids, and other similar issues of concern. These records were obtained from existing reports, and from photograph libraries such as the San Diego Historical Society. A listing and description of selected photographs reviewed for this project is included in Appendix 2.2. The post-closure construction and surface activities were reviewed and summarized. This included review of historical documents, engineering drawings, and examination of aerial photographs to further analyze the post-disposal history of the Mission Bay Landfill.

The scope of the field investigation was based, in part, on the activities conducted during the review of data conducted during development of the Workplan. Each of the field tasks are described and a summary of the results is presented in this Report.

2.4 *Site Conceptual Model and Risk Assessments (Sections 7, 8, and 9)*

A Site Conceptual Model (SCM), generally consistent with United States Environmental Protection Agency (U.S. EPA), State of California Department of Toxic Substances Control (DTSC), and State Water Resources Control Board (SWRCB) guidance, has been prepared, and is described in Section 7. The SCM describes the site setting, contaminant sources and COPC, potential release mechanisms, exposure pathways, and complete receptor scenarios. The SCM was refined following the field investigation and is intended to communicate the overall Site conditions, and the potential for human health and ecological exposure and risk. This task also addressed potential receptors, landfill conditions, fate and transport analyses, as well as the human health and ecological risk assessment.

The three primary standards for conducting this work included the DTSC Preliminary Endangerment Assessment (PEA) guidance, U.S. EPA Risk Assessment Guidance for Superfund (RAGS), and DTSC's Supplemental Guidance to RAGS.

A detailed description of the risk assessment process depends upon the Site-specific data that were collected and analyzed during implementation of the field investigation workplan. A detailed description of the risk assessment work is included in Sections 8.0 (human health risks) and Section 9.0 (ecological risks). The risk assessments followed standard protocols established by the California EPA (Cal-EPA) and U.S. EPA.

2.5 Conclusions and Recommendations (Sections 10 and 11)

Potential alternative remediation options that are considered appropriate for the Site based on the results of the historical, field, and risk assessments are discussed briefly in Section 10. This Report concludes with summary conclusions and recommendations. Detailed summaries of the results and conclusions of the site investigation, historical review, and risk assessments are presented in each of the respective sections. The conclusions describe the primary findings of this Report, and the recommendations have been made based on our technical understanding of the Site.

3.0 HISTORICAL REVIEW (PHYSICAL CHARACTERISTICS)

3.1 *Original Conditions*

Prior to 1946, Mission Bay, originally called False Bay, was a natural estuary of over 4,000 acres (Herron, 1972). A 1930 study of the molluscan ecology of the bay noted the wide variety of different habitats and the high diversity of species observed (Morrison, 1930). A 1957 "Master Plan for Small Craft Harbors" stated that approximately 2,677 acres of mud flats existed in Mission Bay in 1945, prior to significant dredging. Maps and photographs of Mission Bay provide a valuable source of information about the original conditions in the area and the changes made during many years of development, including the period of operation of the Mission Bay Landfill (Site). Appendix 2.2 contains selected aerial and ground photographs from the City of San Diego (City) files, along with an annotated list of photographs and maps reviewed during the historical research on the landfill.

The landfill is located in the area formed by deltaic sedimentary deposits at the mouth of the San Diego River. Maps of the area prior to development of Mission Bay show that the San Diego River discharged alternately into San Diego Bay and Mission Bay. In order to reduce the possibility of sediment influx into the harbor, the river was diverted into Mission Bay by an earthen dike constructed in 1854. An 1859 U.S. Coast Survey map contained in Hertlein and Grant (1944) shows that breaching of the short-lived dike by a flood had allowed the San Diego River to resume flowing into the northern part of San Diego Bay. In 1876 an elevated causeway (the "Government Dike") was constructed south of the present river channel, which was successful in forcing the river to flow northward into Mission Bay. A 1933 map by the U.S. Coast and Geodetic Survey shows that the path taken by the river coincided with channels shown on the 1859 map. The 1933 map also shows the buildup of extensive mudflats into eastern Mission Bay, compared to those seen on the 1859 map. A road and railway on the Government Dike provided access through the area to Ocean Beach and Pacific Beach.

Early aerial photographs show the San Diego River to consist of one main channel flowing northwest through the Site toward Mission Bay. Just north of the Site, the river split into several smaller channels which crossed the mudflats. Numerous other tidal channels ("sloughs") not directly connected with the river also crossed the mudflats. The mudflat areas are indicated on the aerial photographs by a relatively dark color representing dark soils and salt marsh vegetation. A map provided in Morrison's 1930 study of the molluscan ecology of Mission Bay indicates the presence of fine-grained mudflat sediments at the outer fringe of the river delta, with sand predominating in other areas of Mission Bay. The sandy areas can generally be recognized by their lighter color on the aerial photographs. Morrison's 1930 photographs of Duckville, a fishing and hunting lodge, show several buildings constructed on the steep eastern bank of the main channel at a prominent bend of the San Diego River. The exposed mudflats in the channel and several beached boats suggest that the photographs were taken at low tide. The aerial photographs appear to indicate that the area of Duckville was characterized by relatively stable sandy soils above tidal influence.

A soils map of Mission Bay in Morrison (1930) based on a 1915 map by the U.S. Department of Agriculture, Bureau of Soils (USDA), shows that the bulk of the Site was tidal marsh, with Foster Sandy Loam present in the extreme eastern portion of the Site. Outside of the river channel, the mudflats were entirely north and west of the Site. Previous descriptions of the future landfill area as mudflats are clearly incorrect. Ground photographs taken by City personnel prior to the start of landfill operation show the area to consist of sandy soils with sparse scrub vegetation. The marsh-like topography description of the Site in previous studies is also incorrect. The 1930 ecological study shows that, with the exception of the river channel, the marshes were not present within the Site area. The 1930 map indicates the presence of mudflats from Curlew Point (near the present location of Ventura Point) eastward to the shoreline near the AT&SF Railroad, but at a distance north of the future landfill site. In addition to the tidal channel portion of the San Diego River, the mudflats (Morrison's Area 4) were drained along several sloughs, some named (Hardy's Slough, Duckville Slough, Blind Slough). Sediment types observed at stations located along the shoreline of Area 4 indicated the presence of mud, with some sand present in the western and eastern extremities of the mudflats. The 1930 USDA map shows that the Government Dike carried the track of the San Diego Electric Railway. The USDA map shows an outdated location for the proposed Ingraham Street causeway, which was completed in 1929, according to Morrison, but along a different route to form Ingraham Street.

3.2 Early Modifications of Eastern Mission Bay

Aerial photographs from 1928 to 1929 show little development in the immediate area of the Site. Near the eastern boundary of the Site, the AT&SF railroad is clearly shown and forms a consistent point of reference in later photographs. Pacific Highway is not present, but a cluster of dirt roads is visible, forming a small subdivision in the eastern part of the Site. These roads also form a useful point of reference on the aerial photographs until the roads were destroyed by landfill operations and dredging in the late 1950s and early 1960s. The road to the Duckville headquarters is the only road visible toward the mudflat areas and is indicated by a thin light-colored line on the photographs. The San Diego River Channel is clearly shown as a broad dark line of low reflectivity due to the presence of surface water in the channel.

Aerial photographs from 1937 show the early development of Pike Field (or Airport) (also spelled as "Peik" in some documents), with several small airplanes parked at the southern end of the short runway. Pike Field was located north of the east end of the landfill. The roads in the small subdivision in the eastern portion of the Site appear to be more distinct. A speedway with a grandstand was present east of Ingraham Street. Aerial photographs show a dirt road access to an oil derrick marked just east of the speedway on the 1933 map. The San Diego River Channel appears to extend a greater distance to the south, compared with the 1928 to 1929 photographs. The Ingraham Street causeway, completed in 1929, and Pacific Highway are clearly shown in the 1937 photographs. The light-colored concrete bridge of Pacific Highway immediately east of the Site provides a useful reference point for all later photographs, and it can still be clearly recognized just east of Interstate 5.

A 1939 tentative development plan for Mission Bay shows the area of the mudflats as a wildlife preserve extending southward to the San Diego River Channel. However later versions of the plan (1953, 1958) show extensive development of the Fiesta Island and South Shores areas, with only small areas in northern Mission Bay assigned for wildlife uses.

In 1946, dredging and filling of the interior portions of the bay were initiated by the City at Gleason Point (now known as Bahia Point) in the western part of the bay, and in May 1948, the U.S. Army Corps of Engineers (COE) began construction of south and middle jetties at the entrance to the bay (Herron, 1972).

Aerial photographs from the 1940s indicate increasing development in the Site area. The speedway was demolished and appears only as an elliptical scar obscured by an extensive rectangular area of lighter-colored soils which represents an area of disturbance. The nature of the disturbance is not known, but the rectangular area and its boundary roads/dikes remain distinct on later aerial photographs (see also Herron's 1947 photo). An early 1941 aerial photo shows increased usage of Pike Field. A 1949 aerial photograph shows extensive improvements to Pike Field. A number of buildings are present, and numerous small airplanes are parked at the runway. The wartime operations at Pike Field are not shown in any of the readily available aerial photographs obtained in this research. The roads in the subdivision south of Pike Field appear more distinct in the 1949 aerial photographs, and several buildings are visible in the area.

The Site area was greatly modified by the channelization of the San Diego River. This work was conducted in 1949 to 1950 and consisted of the excavation of an approximately 800-foot-wide channel bounded on north and south by raised levee embankments with a layer of rip-rap slope protection along the steep inner banks of the channel (Rick, 1979). The outer slopes of the levees graded more gently into the original surrounding grades. Numerous aerial photographs in the collection of the San Diego Historical Society document the construction of the channel and the new bridges crossing it at Midway Drive and Sunset Cliffs Boulevard. A small subdivision at the west end of the Site, north of the former speedway, was demolished during channelization of the river.

Photographs taken by City personnel in July 1952, immediately prior to start of the landfill operations, show the new San Diego River Channel's north levee and the open, sparsely vegetated area of sand flats to the north. The views to the north and west are unobstructed, and the view to the east shows distant buildings, such as the Presidio, which may be used for orientation and reference.

The location of the former San Diego River channel shown on the figures in this report is based on the 1950s aerial photographs obtained from the City of San Diego and the San Diego Historical Society, many of which are included in Appendix 2.2. Aerial photographs from 1951 and 1952 show the location of the former San Diego River channel shortly after the completion of the new channel and levees, but prior to the start of landfill operations. Aerial photographs from late 1953 show that much of the former channel had been filled during expansion of the landfill.

The figures in the report show the location of the former San Diego River channel as interpreted from the pre-1952 aerial photographs and maps. Although the former channel appears different in the various photographs, mainly due to changes in the amount of water present in the channel, the general location of the channel remains the same on all the photographs. The figures show the maximum width of the former channel seen on the aerial photographs, although the channel was probably full of water only during high tides. Historical maps, such as the 1859 map issued by the U. S. Coast Survey, show that the former San Diego River channel was in the same general location as observed in the later aerial photographs.

3.3 *Landfill Operations*

The development of Mission Bay proceeded concurrently with landfill operations throughout the 1952 to 1959 period. Although documents concerning the landfill operations are sparse, the surrounding development of Mission Bay can be reconstructed by interpretation of the numerous photographs of the area and several important documents which relate the history of development. For the landfill operations, the sequence of events must be reconstructed mainly from aerial photographs, supplemented by City ground photographs of operations at the Site. Only a few engineering drawings of the landfill operations have been located and a few field notebooks for the 1952 to 1954 period were located in City files. There are eyewitness accounts of the disposal of drums of waste in the landfill, but only two photographs were found containing images of individual drums.

Some historical documents with information regarding waste disposal practices in San Diego during the period of landfill operation are included in Appendix 3.1. A summary of the information in the documents is provided in Table 3.1.

The outline of the landfill operations shown on the report figures is based mainly on the interpreted extent of disturbance shown on aerial photographs taken in the 1957-1960 period. It is likely that this outline includes areas in which there was no actual disposal of buried waste. Aerial and ground photographs show that large portions of the area within the boundary were used for stockpiling of various types of waste material. It is not known whether burial of waste occurred in these areas of the landfill operations. In some areas included within the outline of landfill operations, aerial and land photographs show that elongate trenches were excavated and filled with waste. Such areas were noted in the late 1950s photographs of western portion of the landfill. It is possible that the soils between these trenches were not excavated. It is likely that some portions of the area of surface disturbance resulting from landfill operations were never used for the subsurface disposal of waste. Such areas may have been set aside for future use or may have been used mainly as staging areas.

3.3.1 1952–1953

Several vertical aerial photographs are available for 1953. These clearly show the initial landfill operations in the area immediately west of the abandoned river channel. The ground photographs from this initial waste disposal period (starting with

the July 24, 1954 photos) show that trenches were first excavated immediately north of the levee and extended in an east-west direction. The trenches visible in the aerial and ground photographs also appear to be oriented mainly east-west. Ground photographs show that solid waste was dumped directly into these trenches. A dragline is visible in several of the ground photographs. Visual comparison of the cab of the dragline with the soil piles along the levee road indicates that the piles were about 12 to 15 feet high. The depth of the trenches shown in the photos is harder to estimate without a reliable scale, but daily field notes mentioned trenches as deep as 25 feet below grade. The most likely location of such deep trenches was at the relatively higher elevations of the levee embankment, next to the road. Even at these relatively high locations, it is likely that such deep trenches extended downward a significant depth below groundwater, possibly as much as 8 to 10 feet below the water table. Water is visible in some of the trenches in the photos taken during this phase of operation; an easterly view taken on July 17, 1953 is an example. Cover of the waste materials appears to have been conducted on a routine basis, probably using materials excavated from the trenches adjacent to the levee. Access to the initial landfill operations appears to have been from the road on top of the north levee, with trucks dumping on the levee slope adjacent to the road.

Both aerial and ground views show the dumping of solid waste into the old river channel and the adjacent marsh. A 1953 direct aerial photograph shows that the filled area extended about 250 to 300 feet north of the San Diego River Channel levee. A debris dam was constructed across the river channel early in the landfill operations, and the channel was eventually filled (in 1954). Ground photos from April 1953 show that the landfill platform had progressed northward into the low-lying areas of the old San Diego River and adjacent marsh. The top of the landfill cover appears to be at approximately the same elevation as the levee road. Visual comparison of the heavy equipment and trucks shown in the April 1953 photographs with the waste exposed in the working face of the landfill suggests that the combined thickness of waste and cover is about 12 to 15 feet above original grades on the sand flat area. The actual thickness of waste cannot be estimated from the photos because the entire depth of excavation below original grades cannot be observed. Figure 6.1 is a landfill waste thickness (isopach) map as interpreted from soil borings and monitoring well logs. Figure 6.2 is a landfill soil cover isopach map as interpreted from soil borings and monitoring well logs.

Landfill operations conducted at the Site in 1952 and 1953 appear to have extended over an area of approximately 18 acres (Figure 2.1). At the same time, dredging operations in the western portion of Mission Bay were proceeding. Construction of the entrance channel, begun in 1948 by the COE and the City of San Diego, was continued and portions of western Mission Bay were dredged. The City carried out the work in the absence of the COE during the period from 1951 to 1955 because of the Korean War (Herron, 1972).

3.3.2 1954–1955

A major change in the location of landfill operations occurred in 1954 (Figure 2.1). The earlier operations appear to have been largely abandoned, with the new operations located to the east of the old river channel. Possible reasons for the move are that the previous locations were too far from a suitable source of cover soils or that the eastern area was more accessible. City estimator's notes from 1954 indicate that operations were to be conducted in the eastern area during the winter and in the western part of the Site during the summer. The estimator's notes and associated drawing indicate that the northward extent of the landfill was to be determined by the location of the proposed Bay Shore Drive, although the notes contain a comment about the possible available space north of the proposed roadway.

Air and ground photos from 1954 show that most of the landfill activity continued to be within 200 to 300 feet of the levee. Ground view photos of operations on August 25, 1954, show deep east-west trenches excavated close to the levee in an area east of the old San Diego River Channel. Comparison of the exposed walls of the excavation with the dragline shown in the photos suggests that the trenches were excavated to at least 10 to 12 feet below the original grade of the sand flats. Water is present in the trenches. The waste materials in the photos appear to consist predominantly of demolition and landscaping debris, along with occasional tires.

A 1955 engineering drawing of the proposed landfill operations in the eastern portion of the landfill show a relatively thick layer of waste planned for the area. The proposed finished grades for the soil cover of the waste are significantly higher than the elevation at the levee road.

3.3.3 1956–1957

Aerial photographs show that the landfill footprint was greatly expanded during this period. It appears that a substantial amount of fill soil, possibly pumped from dredging operations in the western portions of Mission Bay, was placed at the Site. Aerial photographs show that the northern edge of this fill was noticeably higher than the original ground, and much of the area appears to have been brought up to approximately the same grade as the top of the north levee. Ground photographs suggest that the landfill operations in the central and western parts of the Site may have consisted of trenches excavated into this layer of fill soils. This sort of operation could have proceeded without concern for a lack of available cover soils, and sufficient space was available for the stockpiling of excess soils from the trench excavations. Large soil stockpiles are visible in the photographs of the western portion of the Site. The trenches and soil stockpiles in the western part of the Site were oriented in an approximately north-south direction during this phase of operations.

Ground photographs taken in 1956 of the eastern part of the landfill show numerous soil piles. The piles appear in some of the photos to be eroded, suggesting a period of

inactivity in the area. The aerial photos from March 1956 show soil piles and other evidence of operations in progress at both the east and west ends of the landfill. Ground photos taken in 1956 and 1957 show a fairly wide area of smooth-graded soils, which appear to be at approximately the same elevation as the levee road, with active operations mainly at the northern limits of the landfill.

In early 1957, dredging operations east of Ingraham Street were accelerated. The COE dredged a portion of the main channel and Quivira Basin to a depth of -20 feet below mean lower low water (MLLW). This relatively coarse sand was pumped to the eastern perimeter of the bay to stabilize the mud deposits along US 101 (Herron, 1972). The large area of Quivira basin was excavated, with relatively coarse grained sand pumped to the east to stabilize the soft soils along the eastern shore of the Bay, especially along the west side of Pacific Coast Highway. Historical documents indicate that this coarse-grained sand was placed in the areas planned for recreational beaches under the 1956 general plan for Mission Bay development. Aerial photographs from December 1957 show an approximately 300-foot-wide swath of light-colored soils parallel to the present shoreline of Pacific Passage. This sand deposit formed a wide berm or “beach ridge,” constituting a topographic “high” which influenced the drainage of the Site throughout the remainder of landfill operations and for some time after closure of the landfill. Drainage of the resulting topographic low area was apparently accomplished by leaving open a portion of the old river channel and by excavation of a separate narrow ditch through the sand berm west of the Site. A narrow dike was later constructed on top of the north edge of the sand berm, which accentuated the closure of the basin and allowed disposal of a greater thickness of dredged fine-grained silty muds.

3.3.4 1957–1958

Landfill operations at the Site appear to have continued in the same style as established in 1956 (Figure 2.1). Excellent quality aerial photographs are available for this period which appear to show continued landfill operations at both eastern and western portions of the Site. The extent of operations in the central portion of the landfill is less clearly shown. Some aerial and ground photographs suggest that the central area was used primarily as a staging and stockpile area. Ground photographs show numerous piles of soil and rubble in this area.

An oblique aerial photograph taken on December 7, 1957, shows a dark material in the topographic depression west of the landfill operations. This appears to represent water or saturated soils. Oblique aerial photographs taken a month later, on January 4, 1958, show a narrow ditch excavated across the sand berm, presumably to allow the water to drain from the topographic depression into the bay. The source of the water is unknown and it does not appear to have encroached into the area of landfill operations.

In July 1958, the City initiated a 12-million-cubic-yard dredging contract to complete the development of the east bay. This project was completed in 1963, which essentially completed the City's dredge and fill program (Herron, 1972).

City documents indicate that the dredged soils that were subsequently placed at Fiesta Island and South Shores would present engineering stability problems unless the soils were covered with more suitable sand materials.

According to City documents, Pike Field was condemned in 1957. Aerial photographs from 1957 and 1958 show vegetation returning to the abandoned runway.

3.3.5 1959

During the final year of permitted operation, the eastern boundary of the landfill was extended toward Pacific Highway (Figure 2.1). Aerial photographs appear to show an additional landfill area between the north levee and the abandoned Pike Field. Ground photographs from this period appear to show solid waste placed above levee grade and covered with soil.

Although Pike Field was under condemnation for many years, the City was not able to acquire the property until after 1965.

3.4 *Post-Landfill Activities at the Site*

Following closure of the City's sanitary landfill in 1959, portions of the Site were used for the placement of materials dredged from the eastern portions of Mission Bay. The presence of large quantities of dark muddy soils unsuitable for structural fill continued to present disposal problems. COE and City records indicate that all of the unsuitable materials were pumped to the closed basins of Fiesta Island and South Shores.

Dredging operations in the portions of the bay west of Ingraham Street were completed in December 1959, at about the same time as the closure of the landfill. Initial dredging of the bay immediately east of Ingraham Street produced sandy material suitable for building the dikes at Fiesta Island. As dredging progressed into the eastern bay, the materials encountered consisted of silty clay, which was pumped into the diked area of Fiesta Island and South Shores (area "U" of Patterson, 1965). The dredging operations were completed on August 1, 1961, but the fine silt left certain areas of Fiesta Island and South Shores unusable as described below.

Aerial photographs taken on February 5, 1961 appear to show flooding of the topographic depression west of the Site and portions of the landfill operations in this area. The relatively light-colored soils of the dike constructed on the sand berm and the fill soils of the landfill operations contrast with the dark-colored material within the topographic low area. These dark areas may represent flood waters, although the source of such water is not known. It is also possible that the dark areas represent saturated dredged materials pumped into the area

from other parts of the bay. COE comments indicate that soft soils unsuitable for load bearing construction were systematically pumped into the Fiesta Island and South Shores areas. These areas were prepared in advance with dikes and berms to allow the placement of such dredged materials. These fluid soils were excavated from the dark fine-grained mudflat and channel deposits of the eastern parts of the bay. The presence of dark muddy soils might help to explain the differences in appearance between the two oblique aerial photographs taken on February 5, 1961. The difference is most noticeable in the interior of the bermed area of Fiesta Island, where the north-facing view shows very dark materials very similar in appearance to the bay waters, while the south-facing view shows materials which look like dark soils.

Although the large-scale dredging for bay development was completed in 1961, additional fill materials were placed at South Shores in the 1980s, raising the surface grades in several areas. Construction activities in the 1980s and 1990s, particularly in the area of the South Shores Boat Basin, caused additional modification to the surface.

In August 1988, grading began of the South Shores project. This project included the excavation of a 9-acre cove for use as a boat launching basin and the construction of a 16-acre parking area and other improvements. Available documents indicate that the boat basin was planned to be excavated to a depth of 10 feet below mean sea level (MSL). A concrete boat launching ramp was constructed on the west side of the boat basin. A gently sloping sandy beach was constructed on the east side of the basin. The remaining steep slopes around the basin were covered with rip-rap slope protection. An impermeable geomembrane liner consisting of high-density textured polyethylene (HDTPE) was installed beneath the sandy beach and the rip-rap slope protection. The available as-built drawings of the boat basin do not show the HDTPE liner extending beyond the sandy beach or the slope protection. Filed notes and photographs taken by a representative of the County of San Diego Hazardous Materials Management Division (HMMD) in late August 1988 indicate the excavation of decomposed plant material, wood, plastic, and other debris from a "finger" of the landfill which extended northward into the Boat Basin excavation.

The widely circulated July 20, 2000, article in the *San Diego Reader* noted that some excavation workers at the South Shore site became ill during grading operations in early October, 1988, apparently due to exposure to hydrogen sulfide gas, and that three were hospitalized. Although one of these workers died a short time later, a death certificate obtained by City staff did not identify exposure to toxic chemicals as the cause of death.

4.0 TECHNICAL BACKGROUND

4.1 *Compendium of Existing Reports/Annotated Bibliography*

The City of San Diego (City) Environmental Services Department (ESD) compiled all their documents and reports regarding the Mission Bay Landfill (Site) into one location, and created a document inventory, which SCS used as a base for the attached annotated bibliography. SCS reviewed all the City documents for useful information for this Site assessment, and continued to expand this annotated bibliography as other documents of potential interest became available. Other sources reviewed for pertinent information include the Regional Water Quality Control Board (RWQCB) files and the City of San Diego Local Enforcement Agency (LEA) files. The annotated bibliography is attached as Appendix 2.1.

4.2 *Summary Review of Previous Site Assessment Work*

As part of the current study, we examined in detail the data and conclusions from all available previous investigations for use as a guide for our investigation. Although all maps, field notes, and photographs made available by City personnel have been reviewed in detail, there appear to be no comprehensive reports of the landfill operations. Therefore, it was necessary to use the available information from other sources to reconstruct the history of the operations.

The City has published several historical reviews of the development of Mission Bay Park. Although these reports contain no new scientific data and little information about the landfill, they contain much useful information on the planning and execution of the work performed in building the park and a detailed chronology of events.

The landfill site is within the boundaries of Mission Bay Park (Figure 1.1), which has been highly modified from its original conditions. Figure 2.1 illustrates the phases of landfill operations as depicted by landfill records and aerial photograph interpretation. The early planning for development of Mission Bay Park required careful consideration of the existing conditions in the area. The early investigations of Mission Bay were concerned with the perceived need for improvement of the entrance of the bay to allow better conditions for navigation and recreation. This need, combined with the intention to deal with potential flooding in the channel of the San Diego River, led to the planning for the channelization of the river and the stabilization of the bay entrance. Several investigations were conducted by the U.S. Army Corps of Engineers (COE) to evaluate the physical characteristics of the sediments and soils of the proposed development area. Although most of the data from these early studies were not located or reviewed, it is clear from historical summary documents that the bulk of the work was concerned with the areas of the flood control channel and the western portion of the bay. Numerous sediment samples were collected for geotechnical analysis, mostly in the San Diego River Channel and western parts of the bay, particularly in Quivira Basin. Although some consideration was given to the preservation of designated “wildlife areas” in the early development plans, relatively little attention was given to the environmental aspects of the development.

Existing environmental information for the entire Mission Bay was presented in Roy L. Morrison's 1930 Master's thesis titled "*A Study of Molluscs Found at Mission Bay, San Diego, California, Their Classification and Special Attention to their Distribution.*" Morrison provided extensive comments on the molluscan ecology and the existing sedimentary environments of the Bay prior to development. He also provided a map showing the distribution of sediment types, making a careful distinction between the intertidal mudflat environments, which were extensive in the eastern part of the bay, and the sandier areas, mainly west of the new Ingraham Street causeway (completed in 1929).

The most important scientific study of the physical characteristics of the bay conducted prior to the development of the eastern half of Mission Bay was the 1957 report by Marine Advisers titled "*Mission Bay Development, An Evaluation of Pertinent Oceanographic Factors.*" This report presented a large amount of physical data obtained for evaluation of the proposed changes to the 1956 Master Plan for Mission Bay Development. The development of the eastern half of Mission Bay was emphasized, but the existing and proposed improvements to the western half of the bay were also addressed. The report presented a topographic map of the southeastern part of the bay and discussed soil samples taken in the portion of Mission Bay Park currently known as the South Shores area, including both the new data obtained by Marine Advisers and older COE geotechnical data. Many of the recommendations of the Marine Advisers report appear to have been incorporated into the planning and execution of the final development plan.

No studies appear to have been conducted during the dredging operations to implement the 1956 general plan, but the work was conducted under a very methodical and detailed plan, as related in the chronological sequence of development tasks listed in the City historical summaries. Some small-scale investigations were undertaken in the early 1960s to evaluate the Mission Bay area for proposed City uses, such as sewage disposal and as a site for the use of reclaimed water for irrigation. A 1963 report by Boyle Engineering titled "*Water Reclamation Study for Balboa Park and Mission Bay Park*" presented results of limited soils investigations conducted in the South Shores area (the portion of Mission Bay Park located south of Pacific Passage, and between Ingraham Street and Interstate 5), commenting on the very high salinity values observed in samples of the surface soils derived from dredged materials.

From the early 1960s to the early 1980s, there appears to have been little scientific interest in the South Shores area. With the exception of a few studies of the water quality in Mission Bay, there was relatively little apparent interest in the scientific evaluation of the bay.

In the early 1980s, proposed development in the South Shores area brought greater attention to the landfill. A proposed Ramada Hotel (later referred to as the Renaissance Mission Bay Hotel) site in the eastern portion of South Shores was determined to be partly within the estimated boundaries of the landfill. Woodward-Clyde conducted two investigations of the proposed hotel site (1980 Woodward-Clyde - *Preliminary Soil Investigation, 35 Acre Parcel, Mission Bay Park, San Diego, California*, and 1981 Woodward-Clyde - *Soil and Geologic Investigation for the proposed Resort Hotel in Mission Bay Park, Sea World Drive, San*

Diego, California). These investigations confirmed the presence of significant quantities of refuse beneath a soil cover at the proposed hotel site.

Another geotechnical study performed in 1982 by Geocon titled “*Mission Bay South Shores, San Diego, California, Geotechnical Investigation*” consisted of a soil investigation and geological reconnaissance in South Shores. Geocon drilled eight exploratory boreholes to depths of 30 to 50 feet, and performed tests of physical properties. The borings encountered fill soils underlain by soft bay deposits. Groundwater was found at an average depth of 20 feet below grade, but saturated zones of clayey soils (perched groundwater) were present within hydraulic fills at 2 to 5 feet below existing grades. Geocon noted that the potentially active Rose Canyon Fault system was located approximately 2,000 feet east of the Site.

Although the proposed hotel project was abandoned, community concerns had been raised about the potential hazards from the landfill within the Mission Bay Park and close to urban communities. The level of concern was sufficient in 1983 to cause the City to commission Woodward-Clyde to conduct a more extensive study of the landfill. At the same time, another study was undertaken of the water and sediments of the area by Science Applications, Inc. (SAI). The SAI report, “*Characterization of the Extent of Priority Pollutant Contamination of Mission Bay*,” was issued in 1983. The Woodward-Clyde and SAI studies estimated the baseline for environmental monitoring of the landfill.

The purpose of the SAI investigation was to monitor the water column and sediments of Mission Bay and nearby creeks and rivers for chemical contamination by the organic compounds and heavy metals of the U.S. EPA’s list of priority pollutants. Sampling stations were established in Mission Bay, Tecolote Creek, Rose Creek, the San Diego River Channel, and the San Diego Flood Channel. The samples were analyzed for the 129 EPA priority pollutants; the results showed the bay waters approximating the quality of open ocean water, except for slightly increased levels of mercury. The sediments contained some heavy metals and a few pesticides. According to SAI, the heavy metals presented the most concern of all the priority pollutants. The Mission Bay Landfill was suggested as a possible source of some metals in sediments, particularly chromium, copper and thallium. SAI also recommended a chemical monitoring program.

The November 1983 Woodward-Clyde *Site Assessment Report* provided the results of their investigation performed to determine the limits of the landfill and evaluate the risk presented by it. The study was intended to determine whether hazardous materials were present in the landfill, provide information on the types and concentrations of hazardous materials, assess remedial measures, and recommend further Site studies. The report concluded that the landfill did not pose a significant hazard to humans, and that the landfill was not a significant source of contaminants to water and sediments of Mission Bay or the San Diego River Channel.

In 1985 Woodward-Clyde submitted a *Proposed Ground and Surface Water Monitoring and Post Closure Maintenance Plan and Addendum* to the RWQCB. This report comprised a sampling plan for groundwater, surface water, and sediment analysis and proposed a Site

maintenance plan for the landfill. This report was prepared at the RWQCB request in support of development of the proposed Renaissance Mission Bay Hotel.

The first annual water quality report for the Mission Bay Landfill was produced in January 1986 by the City in compliance with RWQCB Order 85-78. The report contained results of waste and sediment sampling at nine surface compliance points from Mission Bay and the San Diego River. Future sampling at the same compliance points was conducted semiannually for water and annually for sediment. The results of surface water, sediment, and groundwater testing performed in 1986 by S-Cubed Corporation in their report titled "*Analysis of Bay Water, Sediment and Groundwater Samples Associated with the Mission Bay Landfill Site*" were incorporated into the first annual report of 1986. In 1991, a report by ERCE titled "*Evaluation of Surface Water and Sediment Monitoring Program, Mission Bay Landfill*" recommended continuation of the monitoring program. *Annual and Semiannual Water Quality Reports* were submitted by the City through 1996.

From 1994 through 1997 Emcon filed *Water Quality Monitoring Program Status Reports* for the quarterly sampling of the new six-well monitoring well network and the semiannual surface water sampling of Mission Bay and the San Diego River. These reports were submitted semiannually to the RWQCB.

In a 1996 report submitted to the RWQCB by Emcon titled "*Evaluation of Sediment Sampling Program, Mission Bay Landfill*," Emcon concluded that the sediment sampling program was contributing no new information and should be discontinued.

In April 1997, the RWQCB issued Order 97-11 requesting that the City submit a revised water quality monitoring plan. Under the new plan submitted by the City, the frequency of surface water testing was reduced from semiannual to annual, and the number of surface water points was reduced from nine to four. The groundwater network would be sampled quarterly under the new plan, but sediment sampling was not included. Emcon submitted *Semiannual Water Quality Monitoring Program Reports* from October 1997 until Spring 2003.

Along with the intense public scrutiny applied to the studies conducted within the existing framework established by Woodward-Clyde and SAI for the area within the estimated limits of the landfill, concerns were raised about the potential issues at the Sea World facilities to the west. An article about the landfill in the July 20, 2000 issue of the *San Diego Reader* generated additional public interest in the potential for associated health risks presented by the buried waste. Much of the ensuing public discussion of the landfill included comments about the proposed Sea World expansion toward the landfill.

In 1997, Fluor Daniel issued a report titled "*Assessment Report Sea World Lease Expansion*." This report summarized the results of their Phase I and Phase II studies of the Sea World expansion area and provided results of soil and groundwater sampling and analysis. Fluor Daniel noted that the six wells installed in 1996 and 1997 by Ninyo & Moore did not encounter landfill debris. Soil and groundwater samples collected during drilling were analyzed for the presence of gasoline hydrocarbons, volatile and semivolatile organic

compounds (VOCs and SVOCs), and CAM 17 metals. Hydrocarbons were detected in subsurface soil samples from two borings, and the solvents acetone and 2-butanone (MEK) were also detected at depth in some borings. Metals concentrations in the soil samples were below those reported in the 1983 Woodward-Clyde report, and some metals concentrations were suggested as likely to represent natural background levels. A chlorinated solvent, 1,1,1-trichloroethane, was detected in groundwater samples from all but one of the six new wells. The report noted that the 1,1,1-trichloroethane concentrations did not exceed maximum contaminant level (MCL, applicable to drinking water) limits and that no other organic compounds listed in the Basin Plan as contaminants of concern were detected. Metals detected in the groundwater samples included barium, silver, selenium and zinc. Chromium, cobalt, copper and other metals detected in the Woodward-Clyde wells were not found in the groundwater samples from the six new wells.

In 2001, a joint groundwater sampling event was conducted at the RWQCB's request on wells located on the proposed Sea World expansion area and on the City's wells located around the Mission Bay Landfill. The results of this sampling are contained in a 2001 report by Emcon titled "*Groundwater Conditions in the Vicinity of Mission Bay Landfill.*" Of concern was the previous detection of VOCs in groundwater samples from the proposed Sea World expansion area northwest of the landfill. The report concluded that there was no impact on groundwater at the lease expansion site from the City landfill and that further environmental assessment activities in the area were unwarranted. The report further concluded that the landfill's existing groundwater monitoring network was adequate, with no changes warranted.

Recent studies have continued to address specific issues associated with the eastward expansion of Sea World. A January 2002 report by IT Corporation (IT) titled "*Results of Soil Vapor Assessment for Sea World Expansion Plan*" presented data obtained from 28 temporary soil vapor probes placed within the lease expansion, but outside of the known landfill. The study was designed to determine the extent of landfill gas (LFG) migration in the area. Elevated methane concentrations were observed at some of the sampling locations. The methane was suggested to be a product of the decomposition of buried green waste or fill soil containing organic materials. An elevated concentration of hydrogen sulfide was encountered at a depth of 15 feet in one probe (J-24) located in the Sea World parking lot close to the estimated northwest corner of the landfill boundary presented by Woodward-Clyde. Based on their results, IT listed a number of safety practices and regulatory requirements that they believed were applicable to the landfill. IT concluded that the issues raised by the LFG documented in their investigation could be mitigated in future development using common engineering practices.

Two reports by Christian Wheeler, issued in 2000 and 2002, both titled "*Report of Preliminary Geotechnical Investigation, Sea World Atlantis Project, San Diego, California,*" described the geotechnical properties of the soils at the Site. Their soil borings encountered approximately 14 feet of artificial fill materials consisting primarily of silty sands and poorly graded sands. No distinction was attempted in the two geotechnical reports between suspected mechanical and hydraulic fill soils (i.e., whether the soils were placed at the Site by grading equipment and trucks or placed as a mixture of water and sediment from a

hydraulic dredge or similar process.). Quaternary age bay deposits consisting of interbedded sands and silty sands were encountered below the fill. Groundwater was encountered at depths ranging from 7.5 feet to 9 feet below existing Site grades.

4.3 Previous Data Compilation and Review

An initial review and critique of the previous data set was conducted to assess the reliability/usability of the data set and was presented in the Workplan. Subsequently the historical and recently collected analytical data were compiled into a single data base and used in the risk assessments. The health risk assessment (HRA) work included a data compilation and the tables are all included in one appendix to Section 8.

4.4 Summary of Technical Issues/Data Gaps Addressed by SCS Workplan

4.4.1 Hydrogeology

Four new groundwater monitoring wells were installed at the Site in order to provide more information for recognized data gaps, more specifically assessing groundwater conditions in a likely area of highest hydraulic gradient (south of South Shores boat ramp), a potential preferential pathway (within the former San Diego River bed), and in areas previously uninvestigated in order to facilitate the observation of off-site groundwater migration.

Based on the historical review, the historical design and placement of refuse in long, deep trenches may have an impact on the preferential transport of COPC. For example, long east-west trenches were placed in the southern portion of the Site, and in other portions of the Site north-south trenches were excavated and filled with refuse. To address these potential preferential pathways, a few direct-push soil and groundwater samples were collected near the likely down-gradient terminuses of these trenches, as well as monitoring well samples from similar locations. To our knowledge, no previous studies have specifically evaluated potential subsurface discharges of COPC-bearing groundwater from beneath the landfill into Mission Bay, or the potential groundwater/surface water interface and hydraulic dynamics. Four drive points were installed to allow an assessment of the potential impacts associated with groundwater recharge and discharge at the Site boundaries.

Salinity/conductivity/temperature/pH profiles were measured in the groundwater monitoring wells to assess stratification and the potential for isolation of contaminants by a halocline, the potential for pH-controlled mobility of metals, and to support the assessment of the hydraulics of tidal exchange in the groundwater system. No previous investigations performed at the landfill addressed the specific data requirements of the proposed groundwater stratification and tidal influence studies.

Transient flow conditions occur as a result of tidal influences. Tidal influence monitoring was required to develop a detailed understanding of possible temporal variation of hydraulic gradients in response to tidal fluctuations. Monitoring well

elevations and groundwater levels across the Site were measured to a common datum, and existing information on flow rates and water levels in the San Diego River were obtained from the local USGS and Flood Control District of San Diego.

4.4.2 Chemical Analyses

Chemical methods previously used to analyze for metals in the groundwater samples, excluding the sampling completed by SCS, are inappropriate, due to interference from a high concentration of total dissolved solids or salinity.

The potential risk associated with the imported soils used to construct the landfill cover and adjacent soils previously had not been assessed. Review of the history of terrestrial sources of contaminants to Mission Bay suggests that sediments in the bay may have been contaminated by a wide range of potential sources, including large amounts of dredged materials. Thus surface soil sampling and analytical testing for a comprehensive list of analytes was conducted.

4.4.3 Biological Communities and Potential Receptors

Prior to this study, the biological communities living near the project area and potentially sensitive habitats had been qualitatively described. However, they had not been evaluated in light of potential contaminant pathways and exposure resulting from releases from the landfill.

Intertidal habitats had not been described to assess the nature of the intertidal biological assemblages living on and in the sediments and in the water filling the channels. This was an important data gap that needed to be filled. These assemblages could include important target species for bioaccumulation analyses, if there is direct evidence the landfill has had measurable releases to the bay or river.

In the absence of toxicity testing data for the groundwater and sediments, we reviewed the results of groundwater analyses in the scoping assessment to determine if chronic and acute toxicity testing of groundwater is necessary or recommended for future groundwater monitoring programs. Section 9.0 of this Report contains the Ecological Health Risk Assessment.

4.4.4 Historical Data

Documentation of original conditions at the Site was adequate for planning of the investigation. However, little was known about activities in and around the Site during the 1940s. There are few available aerial photographs or maps of the Site for this period, a time when significant military activities were conducted in close proximity to the Site.

Documents concerning the operation of the City's sanitary landfill are scarce, consisting mainly of field notebooks from the 1952 to 1954 period, and a few

engineering drawings and diagrams showing the extent of the landfill or plans for future expansion. Although much of the operational history of the landfill has been reconstructed by interpretation of aerial and ground photographs, there is a significant gap in the record for the 1954 through 1956 period, a time of major expansion of the landfill.

The general sequence of events at the Site following cessation of the City's sanitary landfill operations has been reconstructed from aerial photographs and historical summary documents. However, details of the post-1959 activities are scarce because of the lack of contemporaneous documentation of the large-scale dredging and filling operations associated with the development of Mission Bay. Also, attempts to obtain documentation of the possible placement of sewage and sewage sludge at the Site have so far resulted in little reliable information.

4.4.5 Solvent Wastes

One of the questions regarding the landfill is, based on reports of large amounts of solvent dumping in the landfill, why have we not seen evidence of this in groundwater sampling results. The historical documents provided by the City (Appendix 3.1) have been reviewed and pertinent information, including volumes and ranges in volumes, compiled in Table 3.1. It should be noted that the wastes described in these documents are primarily acids of various kinds, alkaline solution waste, cyanide wastes, magnesium wastes, and paint and oily wastes. There is only one reference to "combustible cleaning solvents (from dry cleaners)." Therefore, it is possible that the quantity of solvents placed in the landfill is not as great as has been speculated, because the majority of the industrial wastes appear to have been other chemicals as listed above and Table 3.1.

Suggested hypotheses as to why substantial quantities of dissolved solvents are not observed in the groundwater samples (in *italics*) and our initial comments are as follows:

- a) *The solvents were dumped somewhere else in the "Mission Bay Landfill", but the boundaries delineated in this report do not include some other, disconnected areas that were not identified in this study.* The extensive review of photographs, maps and other historical documents did not suggest the possibility of other parts of the landfill outside the area studied other than addressed in Section 3 of this report. No other City-operated dumps were found in the vicinity of the study area.
- b) *The waste was actually disposed of by midnight dumping (San Diego River or other convenient locations.)* We have no knowledge of midnight dumping operations which, by their very nature, are undocumented.
- c) *It has been dissolved or biodegraded.* Given the lack of information regarding quantities of solvents potentially placed in the landfill, we consider it impractical to perform calculations to address this possibility. Such calculations would require an

extensive number of assumptions, including estimates of the solubility of the unknown solvent mixture. If solvents were actually a small component of the disposed wastes, that would explain the lack of breakdown products. This topic is addressed further in Section 6.7.3.1.

d) *It is still where it was buried.* It is possible that the waste is degrading and migrating at such a slow rate that after 40 years large concentrations of contaminants are not seen in our sampling and analysis of soil, sediment, groundwater or landfill gases. If this is the case, the wastes do not appear to be leaving the site in quantities of concern.

4.4.6 Thallium Issues

For a number of years, concerns have been voiced about the presence and concentrations of thallium in the landfill. As a result of these concerns Chuck Budinger, a former member of the TAC, gave a presentation about thallium at the TAC meeting on April 25, 2003. The following section is taken directly from the minutes of that meeting:

“Chuck Budinger presented a thorough report regarding Thallium. He and Ann dePeyster, with help from Sylvia Castillo, prepared this item. Below are his conclusions and recommendations for consideration by the TAC for evaluating the presence of Thallium in the environment adjacent to the Mission Bay Landfill.

Conclusions

- 1. Thallium is not classifiable as a carcinogen, but has some toxic effects to humans in large ingested doses or in smaller doses to the skin. Some toxic effects include vomiting and diarrhea in lower doses, and liver and nervous system damage in long-term exposures at higher doses.*
- 2. The No Observable Adverse Effect Level (NOAEL) is approximately 0.25 mg/kg/day-oral of body weight. NIOSH considers Thallium to be immediately dangerous to life and health at an exposure of 15 mg per cubic meter, over an 8-hour period. The Maximum Contaminant Level (MCL) established by the U. S. EPA is 2 parts per billion (ppb) and is the basic standard for drinking water quality. The most accurate Instrument Detection Levels currently in use are only 5 ppb. A number of U. S. EPA testing methods have been used over the years through the various studies conducted at the landfill and over the period of time that the City has conducted its semi-annual monitoring plan for its Closure Permit issued by the Water Board. These testing methods produce different results and have differing detection limits associated with their use. Certain methods using light spectrometry can cause interference by other metals and lead to erroneous results, both for Thallium or the other metals.*
- 3. Industrial uses for Thallium are wide spread, but its use was not particularly concentrated or in large volumes. Thallium can bond with a number of different*

compounds and molecules that have a variety of impacts on the user. These different compounds also have different solubilities in water. For example, oxides and acetates could be less soluble, while sulfates or other salts would be very soluble in water. So, the compound in use can impact the ability to migrate from the landfill.

Recommendations

- 1. The TAC should consider the use of only one testing method to be used for Thallium, and other metals as well. Currently, U. S. EPA Method 6020 uses Mass Spectrometry rather than light to determine concentrations of metals in water or soil. This produces less interference and results in a much better indicator of the true value of the concentrations of Thallium and other metals in the groundwater and soil.*
- 2. The City should also reinstate, voluntarily, the program to sample and test for Thallium on a semi-annual basis with the other metals of concern using the 6020 Method. The City suspended sampling from twice a year to once every five years on recommendation by the San Diego Regional Water Quality Control Board. However, given the variety of testing methods and instrument detection limits associated with those methods, one consistent method should be used over the course of the ensuing investigation and at a more frequent rate. By increasing the frequency of sampling to semi-annual, we should be able to detect any minor trends in Thallium migration from the landfill more accurately.*
- 3. In addition to the numerical analysis, a program for determining the impact on the aquatic "health" should be implemented. This would require a review of the pertinent literature describing the studies completed to date on the health of a variety of aquatic organisms and the development of a comprehensive toxicity study for the area around the landfill. Studies should include Master's and Ph.D. Theses from the local universities as well."*

Analytical Data Interpretation

A table of previous thallium data in surface water, groundwater and sediment samples was compiled and provided by Sylvia Castillo of the City of San Diego (Table 4.1). Some of these data are also included in the Master Data Compilation which has been provided in the appendices of both the workplan and this report. Additional thallium data for sediment samples collected in 1983 are also included in the master table. Soil and landfill waste samples had no thallium concentrations above the detection limit.

SCS has observed that there is a clear pattern of detectable thallium in samples collected and analyzed during the mid 1980's and again in 1996. All of the other samples either had no detectable thallium or the detections were J-flagged by the laboratory, which means that the concentration was less than the detection limit and so is uncertain. It should be noted that for each sampling event, the reported concentrations for each of the samples with detectable thallium are remarkably similar. For example, in October 1985, there are two groundwater samples with

concentrations of 1,000 µg/L thallium and two groundwater samples with concentrations of 1,100 µg/L thallium. During the same time period, there are three surface water samples with concentrations of 1,100 µg/L, and one with 600 µg/L. In November 1986, the four surface water samples have reported thallium concentrations ranging from 270 to 340 µg/L, and the four groundwater samples have reported thallium concentrations ranging from 330 to 380 µg/L. The same pattern can be observed in the data for October 1983, May 1986, November 1987, October 1989, and for August and December 1996, which are the only sampling events for surface or groundwater with more than two reported detectable thallium concentrations.

It is our interpretation that the most likely explanation of these patterns is that they represent the type of interference described by Chuck Budinger during his presentation and in the conclusion above "*Certain methods using light spectrometry can cause interference by other metals and lead to erroneous results, both for Thallium or the other metals.*" The interference may occur due to the close proximity of the Thallium peak to those of other (more common) elements with higher concentrations. This has the effect of raising the base level of the spectrum, which may lead to misinterpretation of concentrations for the metal with the lower concentration (e.g. thallium).

It should be noted that the particular analysis for metals in groundwater that was used during this study was EPA Method 1669, rather than the method suggested by Mr. Budinger (EPA Method 6020). This was done because of the concern regarding the effect of the high salinity in the groundwater and the effect it is known to have on standard methods for metals analysis.

5.0 FIELDWORK

This section of the report presents the results of SCS' field investigation. Supporting laboratory data, boring logs, and task-specific analyses are generally included in appendices referenced to each section. A compilation of historical analytical data has been completed and presented in Appendix 5.1. A summary of the COPCs analyzed in each medium, and the maximum concentrations reported by the analytical laboratories is included as Table 5.25. Statistical analyses presented with the data are used in the risk assessments (Sections 8 and 9). An overall evaluation of the field investigation and previously conducted investigations is included in Section 6 of this Report.

5.1 Background

The following table represents a summary of what we believed to be some of the significant technical issues identified as a result of our research and interpretation of previous data prior to preparation of the Workplan. Potential issues or concerns are identified along with corresponding responses proposed in the Workplan and implemented during the assessment.

Table 5.1: Potential Site Issues and Responses

Issue or Concern	Response/Rationale
Groundwater	
Lack of tidal influence investigations at the landfill in order to develop a detailed understanding of possible temporal variation in hydraulic gradients.	A tidal study was conducted that included placement of 10 water level data loggers in specified monitoring wells and manual measurement of water levels for continuous 28-day time period.
There is a recognized interference problem caused from conventional metals analysis of saline waters.	Implementation of revised metals analysis methodology (Battelle) with ultra-low detection limits to provide more representative and useful groundwater data for the purposes of site assessment and ecological risk assessments.
Lack of sampling documentation of methodology and/or preservation (i.e., field or laboratory sample filtration, sample preservation and type of sample preservative being specified in corresponding field notes, reports, and/or chains of custody).	Additional soil, soil vapor (landfill gas), and groundwater sampling and analysis were conducted.
Lack of depth-specific water quality profiling in groundwater at Site.	Salinity/conductivity/temperature/pH profiles of groundwater in monitoring wells were conducted to assess stratification in the groundwater column within monitoring wells.

Issue or Concern	Response/Rationale
To our knowledge, no previous studies have specifically evaluated potential subsurface discharges of COPC in groundwater into Mission Bay, and the potential groundwater/surface water interface and hydraulic dynamics.	A tidal study, installation of additional monitoring well, and the temporary installation of four drive points were conducted to support an assessment of the potential impacts associated with groundwater discharge.
Lack of investigation relating to hydraulic conditions of the former San Diego River location.	The installation of monitoring wells SCS1 and SCS3 to assess groundwater conditions in a possible preferential pathway within sediments of the former river channel.
Soil	
Soils data generally did not meet data validation criteria (in many cases, the depth of the sample in a boring was not recorded and the distinction between samples that contained waste or that were collected from fill or underlying material was not made).	Additional soil, soil vapor (landfill gas), and groundwater sampling and analysis were conducted.
Lack of soil data from near surface/surface cover materials. To our knowledge, soil samples had not been collected to identify any COPC in near surface fill soil (0 to 12 inches below grade).	Ten locations (some based on suspect areas observed in historical aerial photographs and some based on a simple grid pattern), were selected for analysis and further assessment.
Sediment	
Possible locations of preferential pathways and impacts to sediment were identified during the data review.	Eleven annual sediment sampling events were conducted from 1985 to 1995. The five additional samples were collected to confirm the veracity of the previously collected data, and target possible preferential pathways.
Landfill Gas, Soil Vapor, Surface Emissions	
Lack of surface emissions data and limited LFG and soil vapor data from the Site.	A LFG, vapor, and surface emissions survey was conducted to provide complete coverage within the landfill boundary.

Issue or Concern	Response/Rationale
Landfill Delineation	
Uncertainty associated with landfill boundary. There are portions of the boundary that are estimated to lie within a distance of 100 to 150 feet of their actual locations, so refinement of the estimated extent of the landfill was warranted.	Despite an extensive detailed air photograph review and analysis, additional investigation of the extent, depth and boundary of the landfill was conducted. Soil borings were installed to aid in the landfill delineation boundary, and probes were advanced at the Site as part of the LFG and soil vapor survey to assist in identifying the depth of landfill cover.
Limited historical geophysical survey conducted.	Review of the previously conducted geophysical survey identified limitations and uncertainty regarding the methods employed. A geophysical survey was conducted on a 200-foot grid within (and extending beyond) the landfill boundary. Two types of reconnaissance geophysical surveys were conducted.

5.1.1 Comparison of Analytical Results With Screening Levels

It has been our experience that cleanup or remediation goals are determined on a site-specific or case-by-case basis by an appropriate agency. Typical considerations in setting these goals would include the proposed land use, and the possible threat of impact to human health and the environment, and/or groundwater quality.

In the absence of regulatory or Site-specific agency consideration, several guidance documents have been developed, and include California Human Health Screening Levels (CHHSLs)² developed by the California Environmental Protection Agency (Cal-EPA), Preliminary Remediation Goals (PRGs)³ developed by Region 9 of the U.S. Environmental Protection Agency (U.S. EPA), and 6-month median water quality objectives in the 2001 California Ocean Plan⁴ developed by the California State Water Resources Control Board. These documents are intended to provide preliminary risk screening, soil and groundwater remediation goals for contaminated properties, and provide water quality objectives for the protection of ocean waters. According to the Cal-EPA, "the CHHSLs were developed by the office of Environmental Health Hazard Assessment (OEHHA) on behalf of Cal-EPA, and...were developed using standard exposure assumptions and chemical toxicity values published by the U.S. EPA and Cal-EPA

² Use of California Human Health Screening Levels (CHHSLs) in Evaluation of Contaminated Properties, California Environmental Protection Agency, January 2005.

³ United States Environmental Protection Agency memo, Region 9 Preliminary Remediation Goals (PRGs) 2004 Update.

⁴ California State Water Resources Control Board, California Ocean Plan: Water Quality Control Plan: Ocean Waters of California, 2001.

According to the U.S. EPA, the “PRG table combines current EPA toxicity values with ‘standard’ exposure factors to estimate contaminant concentrations in environmental media (soil, air and water) that are protective of humans, including sensitive groups, over a lifetime. Chemical concentrations above these levels would not automatically designate a site as ‘dirty’ or trigger a response action.”

Analytical data for the media sampled during the assessment were compared to the three criteria mentioned above for screening purposes only in order to provide a comparative analysis of the reported data with the most pertinent regulatory criterion.

5.2 Field and Analytical Program

Each of the field investigation tasks is outlined in Table 5.2. In general, the tasks were designed to develop a sequential understanding of Mission Bay Landfill (Site) conditions. Initially, reconnaissance-level, area-wide testing was completed. The geophysical and soil vapor surveying tasks (Sections 5.4 and 5.5) were minimally invasive methods that provided maps of the entire landfill area. A biological survey (Section 5.6) was conducted as a follow-up to a compilation of existing information to evaluate potential habitats and specific ecological receptors of potential concern. Prior to the SCS assessment, neither a Site-specific soil vapor survey nor a biological survey was performed. A geophysical survey was conducted in 1983, but the survey data were not located.

Once the initial reconnaissance surveys were completed and evaluated, a more invasive soil and water sampling program was conducted. The intent of the invasive sampling was to install additional groundwater monitoring wells, to probe the boundaries of the landfill where uncertainties remained, and to provide analytical data for soil and groundwater as a means to further assess the potential contaminants of concern that occur in the subsurface.

The next phase of work was designed to assess the influence of tidal conditions upon the landfill, as imposed by water level changes in Mission Bay. Following the installation of four new monitoring wells, continuous water level measurements were obtained using pressure transducers equipped with data loggers which were temporarily installed in the wells (Section 5.12). These data provided, for the first time, an assessment of the propagation of tidal water level changes and potential flow directions within the groundwater system. A groundwater sampling program was then initiated (Section 5.13), including the collection of pore water samples obtained using drive points installed in shallow sediments within Mission Bay and the San Diego River flood basin (Section 5.15).

Finally, it is recognized that the proposed field program could have included many other options. These options were evaluated and the reasons for omitting them were provided in the Workplan. The SCS field program was intended to provide a wide range of site investigation methods to evaluate the overall conditions of the landfill.

Table 5.2: Field Investigation Activities

Section	Task	Purpose	Description
5.3	Pre-Field Activities	Develop Community and Worker Health and Safety Plans, and coordinate subcontractors and analytical laboratories.	Supported fieldwork and provides public notifications.
5.4	Reconnaissance Geophysical Survey (non-invasive)	To identify accumulations of metal, refine landfill limits, examine internal structure and lateral extent of the landfill.	Subsurface mapping using magnetic and electromagnetic methods.
5.5.1	Landfill Gas (LFG) Sampling and Analysis	To evaluate the chemical and physical characteristics of subsurface landfill gases.	Direct sampling of LFG for biogenic gases (e.g. methane, H ₂ S, and VOCs).
5.5.2	Near-Surface Soil Vapor Sampling and Analysis	To evaluate the chemical and physical characteristics of vapors in soil between the landfill and ground surface.	Direct sampling of soil vapor within overlying soils for biogenic gases (e.g., methane, H ₂ S, and VOCs).
5.5.4	Ambient Air Sampling and Analysis	To assess upwind and downwind air samples.	Ambient air sampling, conducted along the landfill surface by the APCD, was used to directly test for potential air emissions.
5.5.5	Surface Emissions Monitoring	To measure chemical composition of vapors at the land surface.	Direct sampling of vapors for biogenic gases as above.
5.6	Biological Resources Survey	To prepare map and inventory of known biological resources.	Used to support ecological risk assessment.
5.7	Soil and Groundwater Sampling from Soil Borings	To obtain soil and groundwater samples for chemical and physical characterization and to further delineate the landfill extent.	Completion of soil borings with direct-push and auger drilling methods.
5.8	Surface Soil Sampling	To obtain samples of surficial cover and adjacent fill soils.	Supports risk assessment.
5.9	Sediment Sampling (Mission Bay, San Diego River)	To obtain chemical assessment of river and bay sediments.	Extension of prior sampling efforts.

Section	Task	Purpose	Description
5.10	Monitoring Well Installation	To obtain soil and groundwater samples and to provide groundwater data in recognized areas of the Site that are underrepresented by groundwater information.	Added 4 more wells to monitoring network.
5.11	Groundwater Stratification Study	To assess whether a distinct freshwater/saltwater interface occurs within the groundwater regime beneath the Site.	Water quality parameter measurements were collected throughout the water column in 11 groundwater wells at the Site.
5.12	Groundwater Elevation Tidal Influence Study	To construct water-level maps and evaluate hydraulic interconnection of Site with Mission Bay and the San Diego River.	Install pressure transducers equipped with data loggers in 11 wells to continuously observe water levels during tidal cycles over 30 days. We were also fortunate to observe flood flows in the San Diego River.
5.13	Groundwater Sampling	To sample existing and new monitoring wells.	Low-flow sampling using dedicated pneumatic bladder pumps. Metals analysis with enhanced detection limit methods designed for saltwater.
5.14	Survey of Monitoring Wells	To provide three-dimensional location information for all wells at the Site in relation to a common datum.	Ground surface elevation, casing elevation, stickup elevation, and horizontal survey coordinates measured.
5.15	Drive Point Installation	To obtain samples of pore water within shallow sediments beneath Mission Bay and within the San Diego River channel engineered flood basin.	Temporary piezometers allowed for relative water level measurement and collection of potentially discharging water within sediments.
5.16	IDW Disposal	Wastes generated during installation and sampling of monitoring wells and some soil borings.	Primarily waste soils and sediment, and water used to clean equipment.

The chosen analytical methods for each matrix are presented in Table 5.3. Some of the analyses listed are suitable only for soil, and some for water or vapor. The analytical method for each analysis is listed for each matrix that was sampled. The shaded boxes represent an analytical method that was not conducted for samples collected from that matrix. Table 5.4 provides a duplicate listing of the analyses; however, the number of samples collected from

each matrix is also listed. In addition, each sample type has a letter designation (A through G). The letter designations indicate the following:

- A designates 4 soil borings that were converted to monitoring wells.
- B designates 15 additional soil borings (not converted to monitoring wells).
- C designates 4 groundwater monitoring wells.
- D designates 4 groundwater monitoring wells and the previously existing 8 monitoring wells at the Site for groundwater sampling (however, it should be noted that of the existing 8 monitoring wells, only 7 were sampled, as MBW-7 is located east of Interstate 5 and groundwater conditions in this area were not anticipated to be representative of Site conditions).
- E designates 5 sediment samples.
- F designates 10 surface soil samples.
- G designates LFG and soil vapor samples.

Table 5.3: Analytical Program: Soil, Sediment, Water, and Vapor Analytical Methods

Analytes	Soil	Sediment	Water	Vapor
Volatile organic compounds (VOCs), plus oxygenates and any TIC (tentatively identified compounds) for peaks associated with ethers and esters	EPA Method 8260B		EPA Method 8260B	TO-15
Semivolatile organic compounds (SVOCs)	EPA Method 8270			
Polychlorinated biphenyls (PCBs)	EPA Method 8082A			
Pesticides	EPA Method 8081			
Chlorinated Herbicides	EPA Method 8150 or 8151A			
Polynuclear aromatic hydrocarbons (PAHs)	EPA Method 8310			
Phenol			EPA Method 604	
Total Cyanide	EPA Method 335.2			
TPH (extended run)			8015M DOHS	
Title 22 Metals	EPA Method 6010B/7470A			
Ultra-low detection sampling and analysis for 17 metals			EPA Method 1669/1640 and 1631 for mercury*	
Fluoride			EPA Method 340.1*	
pH	EPA Method 150.1		EPA Method 150.1*	
Alkalinity			EPA Method 310.1*	
Chloride			EPA Method SM 4500-B*	
Specific Conductance			EPA Method 120.1*	
Total Dissolved Solids			EPA Method 160.1*	
Hardness			EPA Method 130.2*	
Nitrate			EPA Method 352.1*	
Sulfate			EPA Method 375.4*	
Total Organic Carbon			EPA Method 415.1	
Non-methane organic compounds (NMOC)				EPA Method 25C
Biogenic/fixed gases: Oxygen, carbon dioxide, methane, carbon monoxide, nitrogen				EPA Method 3C
Sulfur gases: Hydrogen sulfide, carbonyl sulfide, carbon disulfide, mercaptans				EPA Method 15/16 SCAQMD Method 307.91
Total organic compounds (TOC)				EPA Method 25A

Note: Shaded boxes indicate analyses that were not conducted for indicated media.

* indicates surface water sampling; all others analyses listed for water indicate groundwater sampling plan.

Table 5.4: Analytical Program: Location, Sample Type, and Number of Analyses

Analytes	Location/Sample Type/Number of Analyses						
	Soil from borings (A) converted to monitoring wells	Soil/groundwater from direct-push borings (B)	Groundwater from drive points (C)	Groundwater from monitoring wells (D) ¹	Sediment samples (E)	Surface soil samples (F)	Landfill gas and vapor samples (G)
VOCs	0	0/10	4	11	5	10	0/10
Semi-volatile organic compounds (SVOCs)	23	24/13	4	11	5	10	0/0
Polychlorinated biphenyls (PCBs)	0	0/0	0	0	5	10	0/0
Pesticides	0	0/0	0	0	5	10	0/0
Chlorinated Herbicides	0	0/0	0	0	5	10	0/0
Polynuclear aromatic hydrocarbons (PAHs)	0	0/0	0	0	5	10	0/0
Title 22 Metals	23	24/0	0	0	5	10	0/0
Ultra-low detection sampling and analysis for 17 metals	0	0/0	4	11	0	0	0/0
Cyanide	0	0/0	0	0	5	10	0/0
Fluoride	0	0/13	4	11	0	0	0/0
pH	0	0/13	4	11	0	0	0/0
Alkalinity	0	0/13	4	11	0	0	0/0
Chloride	0	0/13	4	11	0	0	0/0
Specific Conductance	0	0/13	4	11	0	0	0/0
Total Dissolved Solids	0	0/13	4	11	0	0	0/0
Hardness	0	0/13	4	11	0	0	0/0
Nitrate	0	0/13	4	11	0	0	0/0
Sulfate	0	0/13	4	11	0	0	0/0
Non-methane organic compounds (NMOC)	0	0/0	0	0	0	0	0/10
Biogenic/fixed gases: Oxygen, carbon dioxide, methane, carbon monoxide, nitrogen	0	0/0	0	0	0	0	0/10
Sulfur gases: Hydrogen sulfide, carbonyl sulfide, carbon disulfide, mercaptans	0	0/0	0	0	0	0	0/10
Total organic compounds (TOC)	0	0/0	0	0	0	0	50/10

Notes: 1 = One sampling event for groundwater included the wells SCS1 through SCS4 and seven of the eight previous wells (excluding MBW-7 due to the location of this well).

Equipment blanks, trip blanks, and duplicate samples were collected during monitoring well sampling.

5.2.1 QA/QC, Comparison of Detection Limits and Regulatory Criterion

Data Quality Objectives (DQO) are quantitative and qualitative criteria that clarify study objectives, define appropriate types of data to collect, and specify the tolerable levels of potential decision errors. The use of DQO during the assessment improved planning effectiveness, design efficiency, and defensibility of results and decisions. They also were utilized to assure that appropriate data (type, quality, and quantity) were generated from the assessment. An example of the implementation of DQO for this assessment is the addition of metals analysis methodology (EPA Method 1669/1640) that produced lower detection limits, and ultimately data that is arguably more representative of the actual conditions at the Site. The assessment that the implementation of DQO has produced more representative data is reached during the Data Quality Assessment (DQA). The DQA was used to determine if the collected data were adequate for their intended use and if they provide “sufficient evidence” to draw conclusions. The reported detections of COPCs in different media sampled at the Site are at concentrations that are comparable to the applicable water quality criteria used for screening evaluation discussed earlier in Section 5.1.1. This is due to the fact that the laboratory detection limits for specific analytes were adequate to utilize the reported analytical data for the intended purposes of characterization and risk assessment.

5.2.1.1 QA/QC Samples

Three QA/QC samples (trip blank, field blank, and a duplicate sample) were collected during the metals analysis groundwater sampling event to evaluate potential sources of contamination. The purpose of the trip blank (TB) was to provide an assessment of potential contamination during transport of the sample containers to and from the lab. Any contamination detected in this blank is assumed to have occurred during transit of the sample containers to and from the laboratory and represents transport contamination.

The purpose of the field blank (FB) was to provide an assessment of the potential for the collection procedure to contribute contamination. Any contamination detected in this blank above that observed in the trip blank is assumed to have occurred during the sampling event and represents contamination due to sampling methodology.

The duplicate groundwater sample (SCS5) was collected to verify the accuracy of the laboratory analysis by submitting two co-located samples that are expected to produce similar results.

The analytical results of the TB, FB, and duplicate sample are presented in Table 5.21. The reported analytical results for the three QA/QC samples suggest that it is unlikely that contamination from equipment, transportation, and/or laboratory analysis affected the reliability of the data.

In addition, the laboratories performed standard internal QA/QC during sample analysis and review of the analytical results prior to issuance. The various laboratory reports and associated QA/QC are included in the appendices. QA/QC review was performed on the analytical data and is summarized in Appendix 5.22. Calibration logs for instruments used during the fieldwork are included in Appendix 5.23.

5.2.2 Summary Statistics of COPCs

The COPCs that have been identified in soil, sediment, groundwater, and soil vapor samples collected at the Site during previous and recently completed assessment work by SCS, are presented in the following table. Analytes shown in boldface were detected in samples for the first time during the recently completed assessment.

Table 5.5: Contaminants of Potential Concern (COPCs)

Type of COPC	Specific Analytes	Media Affected
Volatile Organic Compounds (VOCs)	acetone, benzene, bromodichloromethane bromoform, butane , 2-butanone (MEK), carbon disulfide, carbon tetrachloride, chlorobenzene , chlorodifluoromethane , chloroform, diethyl ether, 1,2-dichlorobenzene , 1,4-dichlorobenzene, dichlorodifluoromethane , dichlorofluoromethane , cis-1,2-dichloroethene, 1,2-dichloropropane, diethyl ether, ethane , ethanol , ethylbenzene, hexane , hydrogen sulfide , isopropylbenzene , methylene chloride, MTBE (methyl tertiary butyl ether), pentane , propane , 2-propanol , toluene, trichloroethene , 1,2,4-trimethylbenzene , xylene, vinyl chloride	Soil, Surface Water, Groundwater, Soil Vapor (LFG)
Semi- Volatile Organic Compounds (SVOCs)	Bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, 4-chlorophenyl phenyl ether, dichloroaniline, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, diphenylamine, diethylphthalate, dimethylphthalate, dioctylphthalate, di-n-butylphthalate, naphthalene, 3-nitroaniline, nitrobenzene, phenol	Soil, Surface Water, Groundwater
Polynuclear Aromatic Hydrocarbons (PAHs)	acenaphthene, acenaphthylene, anthracene, benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenzofuran, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, 2-methylnaphthalene, naphthalene, phenanthrene, pyrene	Soil
Pesticides	Aldrin, α -BHC, β -BHC, δ -BHC, γ -BHC, 4,4'-DDT, 4,4'-DDE, 4,4'-DDD, dieldrin, endosulfan sulfate, endrin aldehyde, heptachlor, p,p'-DDE, p,p'-DDD, p,p'-DDT, pentachlorophenol	Soil, Sediment
Metals	arsenic, chromium, lead, mercury	Soil, Sediment, Groundwater

Notes:

Analytes in **boldface** detected for the first time in media samples collected during the execution of the assessment activities performed by SCS.

Statistical analysis of previous and recently collected analytical data were completed as part of the Human Health Risk Assessment and Ecological Risk Assessment sections of this Report (Sections 8 and 9) to determine and identify the average and maximum concentrations of any chemical contaminants and distribution within the boundaries of the Mission Bay Landfill.

The “new” COPCs identified by SCS are predominantly volatile organic compounds detected in groundwater collected from soil borings and TO-15 analysis of landfill gas samples. The detection of these ‘new’ COPCs may be explained from the addition of a new sample medium (landfill gas) and the associated analysis to the sampling program at the Site and/or may be representative of chemical species generation through the processes of chemical degradation.

5.3 Pre-Field Activities

5.3.1 Health and Safety Plan Preparation

Worker safety during the site investigation of a landfill requires safety procedures that recognize potential hazards specific to former landfills. Gases such as methane, hydrogen sulfide, vinyl chloride, carbon dioxide, nitrogen, and oxygen can accumulate in landfills. The accumulation of these gases or the depletion of oxygen in a suitable environment can result in the formation of an asphyxiant or a potential explosive. These are only some of the hazards associated with landfill investigations that are not generally common to other sites. For these reasons and others, a health and safety plan for work conducted at the Site and workers within the “exclusion zone” was required pursuant to the regulations found in 29 Code of Federal Regulations (CFR) Part 1910.120 and California Code of Regulations (CCR), Title 8, Section 5192.

A health and safety plan was prepared for the proposed work scope, which outlined the potential chemical and physical hazards that may be encountered during drilling, sampling and other proposed activities on the Site. The appropriate personal protective equipment and emergency response procedures for the anticipated Site-specific chemicals and physical hazards was detailed in this plan. SCS and contracted personnel involved with the proposed fieldwork were required to understand and sign this document in order to encourage proper health and safety practices.

5.3.2 Community Health and Safety Plan Preparation

A Community Health and Safety Plan (CHSP) was implemented during the execution of fieldwork. The primary community health and safety concerns for this Site are the accessibility of the landfill to the general public, odors or the release of landfill gas (LFG) that may be encountered during investigative procedures, and other hazards associated with field investigations. A copy of the CHSP is included in Appendix 5.2.

5.3.3 Evaluation of Potential Wildlife and Ecological Conflict

A biologist with Merkel & Associates of San Diego, California, who has local Mission Bay-specific experience, conducted a field survey of ecological habitats and potential ecological receptors. Both flora and fauna were evaluated. The survey was preceded by a literature review of documents specific to the project area.

The purpose of the biological resources survey was to directly support the ecological risk assessment. Specific species of flora and fauna were identified and the health of their habitat was evaluated. A copy of the biological survey report is provided in Appendix 5.3 of this Report.

5.3.4 Subcontracting and Mobilization

Prior to mobilizing for fieldwork, SCS notified and scheduled subcontractors, including laboratory services, drilling companies, specialized equipment and delivery contractors, and waste disposal transporters. Prior to drilling at the Site and in accordance with state law, SCS notified Underground Service Alert (USA) to locate any subsurface utilities. In addition, SCS notified and coordinated with the pertinent City departments and staff prior to field investigations to secure the necessary permits required for access to all portions of the Site.

5.3.5 Soil Boring and Monitoring Well Permit Requirements

In accordance with permit requirements established by the County of San Diego Department of Environmental Health (DEH), any soil boring advanced to a depth greater than 20 feet below grade or which encounters groundwater, or the installation of a monitoring well, requires an approved permit. SCS prepared and submitted the necessary soil boring and monitoring well installation permit application for the installation of monitoring wells and the advancement of soil borings accompanied by the appropriate fees to the DEH. The permit application reflected the proposed well construction and was signed by a professional geologist. The DEH issued permit LMON102307 on June 14, 2004. A copy of the issued permit is included as Appendix 5.4.

As part of the permit requirements, SCS prepared a “60-day report” to the DEH, which provided the well design, soil and monitoring well logs, a Site plan, and corresponding analytical data, and was signed by a professional geologist.

5.4 Reconnaissance Geophysical Survey

The purpose of the geophysical survey was to provide non-invasive testing of the landfill at a reconnaissance level. Two different types of surveys were conducted. The first was a magnetometer survey used to develop a map to identify areas of metallic debris that could potentially be associated with accumulations of hazardous waste, related, for example, to buried drums. The second survey that was conducted included three electromagnetic (EM)

profiles to examine the electrical conductivity of the subsurface with depth. The intent of the EM profiles was to identify changes in the subsurface related to the landfill and potentially to identify underlying features such as the former San Diego River channel that is known to have formerly crossed the site.

The results of the surveys are contained in a report, dated October 8, 2004, entitled *Geophysical Survey of the Mission Bay Landfill*, by 3dgeophysics.com. It is included as Appendix 5.5A. Summaries of the methodologies and the findings are included in this section.

Geophysical surveys were also conducted in 1983 by Woodward Clyde Consultants (WCC). The results of the prior surveys are discussed in this section and were used to support the 2004 survey design as appropriate. An excerpt from their report is included in Appendix 5.5B.

5.4.1 Survey Design

Both the magnetometer and the EM profile surveys were conducted using a GPS-based data collection system where the measurement instruments were set up to automatically collect data as the survey was run. The equipment was towed behind a small rubber-wheeled utility tractor and its position automatically recorded at all times by a Trimble Ag 114 Differential Global Positioning System (DGPS) (refer to <http://www.trimble.com/gps/dgps.html> for additional details). The differential system provided for sub-meter accuracy by operating a stationary GPS system and a roving GPS receiver located with the survey equipments. The use of two stations allows for more precise GPS locations. During operation the instrument location was simultaneously recorded with the measurements during each of the surveys. The magnetometer data were collected at a sampling rate of 10 samples per second and the EM data were recorded at a rate of 5 samples per second. The surveys were typically conducted at a rate of 2 to 5 miles per hour (roughly 3 to 8 feet per second), depending on terrain.

5.4.1.1 Magnetic Field Measurements

Measurements were conducted along 100-foot spaced gridlines oriented north-south and east-west across the landfill surface. Data were collected at less than 1-foot intervals along the survey lines. (refer to <http://www.geometrics.com> or Appendix 5.5A for more details). Roughly 212,000 measurements were obtained over a 214-acre area. The line coverage is shown in Figure 5 of Appendix 5.5A.

The field survey consisted of perpendicular survey lines oriented north-south and east-west because review of historical air photographs has shown that the landfill was constructed using trenches that were typically oriented either north-south or east-west. Thus the survey lines were intended to be parallel and/or perpendicular to these trench structures.

The magnetic field is a vector quantity (three-dimensional) with both magnitude and direction. Near-surface magnetic objects such as tanks, drums, and pipelines result in high vertical gradients in the local magnetic field intensity. Measurement of the vertical magnetic gradient, called magnetic gradiometry, is particularly useful for locating metallic objects. Two Geometrics 858 Cesium vapor magnetometers vertically separated 1 meter apart were used during the survey. The difference between the two measurements was calculated at each measurement point to calculate the vertical gradient. Because gradient measurements were used, the daily variations that occur in the magnetic field did not affect the survey and no baseline measurements were necessary.

5.4.1.2 *Electromagnetic (EM) Conductivity Profiles*

Three survey lines were conducted to examine cross sections of the landfill in the vicinity of the historical San Diego River Channel and within initial landfill phases (developed from 1953 to 1956). The survey included three profile lines. Line 1 was 1165 feet, line 2 was 885 feet, and line 3 was 2410 feet in length. Lines 1 and 2 were roughly north-south and were bisected by the east-west trending line 3. The locations of the survey lines are shown in Figure 5.1.

The EM surveys were conducted with a Geonics EM-34-3XL (for further details refer to the manufacturer's description at <http://www.geonics.com> and in Appendix 5.5A). This instrument uses two loop antennas that are placed 10, 20, and 40 meters (32.8, 65.6, and 131.2 feet) apart. Three sets of reading are obtained that correspond to increasing depths of investigation. As a general rule of thumb, the depth of penetration is expected to be approximately 20 to 30 percent of the dipole antenna spacing, or approximately 25 to 40 feet. The depth of investigation reported in Appendix 5.5A is approximately 10 meters (32.8 feet). Thus it is anticipated that the measurement depths were within the range of depth of the former river channel.

5.4.2 1983 Geophysical Survey

A Site-wide geophysical survey was conducted in 1983 by WCC. The survey included the use of two types of geophysical surveying instruments. The results were provided only in a qualitative graphical format, where features identified in the subsurface were classified as strong, moderate, or weak magnetic anomalies. These categories were intended to generally correspond to the amount of metallic materials within the subsurface. An attempt was made to differentiate between shallow and deep responses (greater than 15 feet below ground surface) for the strong magnetic anomalies based on comparing the response of the two geophysical survey instruments as indicated by the notations made on the survey results map.

The 1983 survey was conducted along 500-foot gridlines for most of the landfill, and along 250-foot gridlines for the portion of the landfill located east of Sea World Drive. A copy of the map is included in Appendix 5.5B. A copy of the text that

described the fieldwork is included in Appendix D of Appendix 5.5B. However, no field data were included in the WCC report.

The survey instruments for the 1983 survey included:

5.4.2.1 *Magnetometer (EG+G Model 816)*

This is an instrument that measures the total strength of the earth's magnetic field. The field strength is affected by the presence of ferrous materials that act to locally "focus" the magnetic field and thus provide a means to detect ferrous debris occurring in the vicinity of the magnetometer.

5.4.2.2 *Geonics EM-31 Conductivity Meter*

This is an electromagnetic measurement instrument that consists of two coil antennas mounted on a horizontal, hand-held boom. An updated version of the instrument remains in production (for further details refer to the manufacturer's description at <http://www.geonics.com/em31.html>). The instrument operates in the frequency domain and one of the antennas generates an electromagnetic signal that propagates into the ground. The signal is received by the other antenna on the instrument and the relative response provides a measure of the electrical conductivity of the ground. As noted in the 1983 report, the EM-31 was found to respond strongly to variations in near-surface salinities caused by salt crusts that occurred in topographic depressions. The occurrence of salt crusts is likely related to the evaporation of saltwater from within the hydraulic fill that was placed on the landfill as cover soil. As a result, since electromagnetic energy is rapidly attenuated with depth in highly conductive soils, the relative depth of penetration of the EM-31 signal was likely quite limited.

The 1983 survey was performed along survey lines spaced either 500 feet or 250 feet apart. Review of the map suggested that a minimum 200-foot-grid spacing (or better) is needed to provide sufficient data density for contouring features observed within the landfill. As noted above, none of the original field data have been located. The EM-31 data are described as being able to differentiate between shallow and deep features where a 15-foot depth is indicated. While the instrument has a shallow and deep testing mode, the effective depth of penetration depends on the electrical conductivity of the subsurface and no data interpretations were reported that would substantiate the claimed depths of penetration.

The results of the 1983 survey were summarized in a map using very qualitative descriptions. None of the survey data were located. As a result, a meaningful comparison with the current survey cannot be made.

5.4.3 2004 Survey Results

The objectives of the two reconnaissance geophysical surveys conducted in 2004 were to:

1. Map the occurrence of ferrous metals within and around the landfill,
2. Further delineate the boundaries of the landfill, and
3. Examine the potential changes in salinity that may occur where groundwater flows from the San Diego River Channel to Mission Bay along the former course of the San Diego River.

After processing of the geophysical data, the following observations have been made.

5.4.3.1 Magnetometer Survey

As previously noted, the magnetometer survey provides an indication of the presence of metallic objects and debris in the subsurface. The instruments also respond to aboveground features such as light poles, electrical lines, and automobiles. Since the Mission Bay Park is active and developed, there were numerous features detected by the survey. Roadways are especially evident due to the associated utilities and other cultural features built within the right-of-ways.

Review of the results of the magnetic gradiometer survey from west to east indicated the following by subarea (Figure 5.1):

- **Sea World Parking Lot.** Numerous linear spots are evident, related to the parking lot lighting and utilities.
- **Unpaved Parking East of Sea World.** Given the absence of utilities, the magnetic responses appear indicative of random occurrences of metallic debris.
- **Mission Bay Parking Lot and Entrance, Sea World Drive, Friars Road.** Strong magnetic signatures are evident due to cultural features (utilities, fencing, etc.) associated with the roadways.
- **Irrigated Area South of Boat Basin.** Metal pipelines were noted to occur in this area. Limited surveying was conducted to avoid damaging the landscaped area.
- **Landfill and Fill North of Sea World Drive.** This area is relatively “quiet,” and has little cultural interference. Just a few magnetic features were recorded, none of which are indicative of extensive accumulations of metallic debris.
- **Landfill South of Sea World Drive and Friars Road.** There is an area within the landfill located south of the intersection of these roads that is suspect.
- **Landfill and Fill East of Sea World Drive.** Coincident with the least amount of soil cover, this area has the most extensive magnetic anomalies observed during the survey. There is a north-south oriented utility corridor that crosses this area.

Overall, the most significant “non-cultural” features were observed to the east of the intersection of Friars Road and Sea World Drive. This is also an area where the soil

cover is relatively thin, so metallic debris is likely to be closer to the surface and to generate a stronger response. Borings B3, B13, and B14; and well SCS2 are located hydraulically downgradient of this area.

5.4.3.2 EM Cross Sections

The EM cross sections are intended to provide for an interpretation of the electrical conductivity of the landfill and adjacent fill soils. Much of the fill soil was placed as hydraulic fill obtained by dredging from the saltwater environments of Mission Bay and are anticipated to be highly saline and highly conductive. Variations in the electrical conductivity profiles are anticipated to occur as a result of less conductive, fresher waters from the San Diego River flowing across the landfill, as a result of the different fill sequences within the landfill, and as a result of differences in soil moisture content.

Three profiles were conducted and are presented in terms of electrical resistivity with depth. The data interpretation methods are described in Appendix 5.5A. Resistivity is the same as resistance used to describe a conductive wire, except it refers to a volume. Sediments and soil containing salt water will have a lower resistivity than those containing freshwater. Dry soils will have a higher resistivity than either. Since the measurements are volume-based, the effect of paving is low, except that pavement will control soil moisture. The EM measurements will also respond to metallic objects. Here the surveys were generally conducted to minimize crossing major utility corridors or roads. However, cultural features will also affect the EM data.

All of the cross sections show decreasing resistivity with depth, indicative of increasing saturation. The approximate depth of penetration was about 10 to 15 meters.

Line 1 (North-South; Figure 9 of Appendix 5.5A).

The southern end of the line begins within the landfill and is located within the paved parking lot of Mission Bay Park. The line extends northward across the landfill boundary towards Mission Bay. The northern portion of the line is within an unpaved area, as indicated by the increased thickness of high resistivity soils (shown as reds and yellows).

The EM profile depicts two different responses, both primarily observed in the upper section of the profile. The shallow portion of the southern half (from approximately 2 meters and up) shows a discontinuous mixture of red and yellow colors that become continuous on the northern half of the profile. The position of the change is consistent with the edge of the parking lot.

Line 2 (North-South; Figure 10 of Appendix 5.5A).

This line is entirely within an unpaved area. The southern portion of the line overlies the landfill and the northern portion extends past the boundary onto fill soils adjacent to Mission Bay.

This EM profile appears to be relatively consistent from south to north. The northern third of the upper part of the section is north of the landfill and does have a different character. However, the landfill boundary does not appear to be readily identifiable in the cross section. The northern part of the section does show a change in the upper soil horizons.

Line 3 (East-West; Figure 11 of Appendix 5.5A).

This line is perpendicular to lines 1 and 2 and roughly bisects both of them. The western end of the line is within the Mission Bay parking lot. South of the boat basin it crosses an irrigated landscaped portion of the park. The line is entirely within the landfill and the eastern third of the line underlies an unpaved area.

This profile is perpendicular to the former San Diego River Channel. Three features are evident:

1. A zone of high-resistivity (red) between lines 1 and 2 that extends to depth. This is interpreted to be the effect of freshwater irrigation. It is not expected that the water will remain fresh at depth, so the deeper portion of the feature is likely to be an artifact of the data processing. A review of water chemistry data summarized in Figure 6.7 indicates that saline conditions occur in the groundwater.
2. Higher resistivity materials occur along the surface to the east of the irrigated area noted above. These correspond to the unpaved soil cover on the landfill.
3. Lower resistivities with depth occur on the eastern portion as compared to the western portion of the profile. This area is where the greatest amount of flow occurs across the landfill (from south to north) when floodwater occurs in the San Diego River. However, the processing of the data may have caused the lateral variation. A clear identification of the river channel was not made.

In summary, the EM profiles did not produce sharp, distinct images of the subsurface indicative of the landfill boundaries or of the former river channel. The shallowest portions of the profiles may be indicative of lateral variations in fill soil associated with unsaturated landfill trenches, but these variations are partially obscured by the effects of the uppermost soils during data processing. The most striking feature identified in the profiles was the irrigated area depicted by higher resistivities in Line 2. The electrical resistivity contrast is due to the flushing of saline vadose zone sediments by freshwater irrigation.

5.5 Landfill Gas Emissions/Migration Assessment

Municipal solid waste (MSW) landfills typically contain gas mixtures generated from the natural decomposition of organic wastes and vapors from volatile compounds present in the waste. Volatile organics are produced by biological processes, residual chemicals, or chemical reactions in the landfill. Transport mechanisms, such as diffusion, convection, and

displacement, potentially may transport a volatile constituent present in the vapor phase from the refuse into the surficial soils, and to the atmosphere.

Landfill gas (LFG), consisting primarily of methane (CH₄) and carbon dioxide (CO₂), is produced by the actions of microorganisms in the landfill under anaerobic conditions. Initially decomposition is aerobic until the oxygen supply is exhausted. Anaerobic decomposition produces relatively high concentrations of methane and CO₂. This two-stage process consists of altering complex organic material into simple organic materials by a group of facultative (can switch from aerobic to anaerobic) bacteria and anaerobic bacteria, commonly called “acid formers.” Then the process continues to include consumption of these simple organic compounds, normally organic fatty acids, by methanogenic bacteria to form methane and CO₂.

LFG typically consists of approximately 50 percent methane, 50 percent CO₂ by volume, and trace amounts of non-methane organic compounds (NMOCs). Other constituents of landfill gas can include ammonia, hydrogen sulfide, nitrogen, oxygen, and carbon monoxide, along with a variety of volatile organic compounds (VOCs). Organic air emissions from landfills may include some toxic compounds and hazardous compounds with carcinogenic and non-carcinogenic health effects.

Degradation of halogenated volatile organic compounds, such as the solvents tetrachloroethene and trichloroethene, also occurs within landfills due to the anaerobic conditions that occur. These compounds sequentially degrade, ultimately to vinyl chloride, ethene, and ethane. The relative ratio of the “parent” compounds to the degradation compounds can be a useful indication of the state of solvents within the landfill.

SCS conducted an LFG emissions/migration assessment (EMA) to assess the type and amount of various chemical emissions from the Mission Bay Landfill. The EMA consisted of the collection of the following types of samples:

- Landfill gas samples from within the refuse prism
- Near-surface soil vapor samples from the cover of the Mission Bay Landfill
- Surface emissions samples.

An agreement was reached with the San Diego Air Pollution Control District (APCD) where the APCD provided technical support to this investigation. They provided air sampling services for:

- Upwind and downwind sampling of ambient air.

5.5.1 LFG Sample Collection and Analysis

SCS collected and analyzed LFG samples in general accordance with Tier 2 sampling and analysis techniques prescribed by the United States Environmental Protection Agency (U.S. EPA) as part of the New Source Performance Standards (NSPS) for

MSW landfills (40 CFR, Part 60, Subpart WWW). This sampling provided a characterization of the raw LFG produced in the Mission Bay Landfill.

Under Tier 2, NSPS require a minimum of two samples be collected per hectare (2.47 acres) of existing landfill area, not to exceed a total of 50 samples. The Mission Bay Landfill site is approximately 113 acres, which equates to 46 hectares, or 92 total samples. Therefore, in accordance with Tier 2 guidelines, a maximum of 50 samples would be collected. Supplemental sampling was conducted, however, to further delineate areas where elevated concentrations of vinyl chloride and methane were initially reported.

The 113-acre landfill was divided into 50, 2.3-acre (approximately 100,000 square feet) grids, with one randomly located sample proposed per grid to evenly distribute the 50 proposed samples. However, four grids were not sampled due to low quality LFG. Figure 5.2 depicts the landfill gas and near-surface sample locations and composite sample grouping explanation.

Sampling was conducted over a 6-day period from May 25 through June 2, 2004 by SCS and H&P Mobile Geochemistry (H&P). Two samples were collected per location from a sample probe driven into the ground by a hydraulic truck-mounted drill rig operated by H&P, or by hand when necessary. The deeper sample was typically collected from within landfill material, generally targeting a minimum depth of 1.0 meter below the bottom of the landfill cover. The shallower location was collected from above the interpreted top of the landfill material, generally targeting at least 1.0 meter above the landfill material, but generally no shallower than 2 feet below grade. A LFG sample and a surface (SUR) sample were then extracted from adjacent borings and composited with other LFG or SUR samples, respectively, within evacuated cylinders (SUMMA canisters). An additional LFG and SUR sample were collected and similarly composited within light-shielded Tedlar bags for sulfur analysis.

5.5.1.1 Sampling Equipment

The sampling equipment consists of four main components: the sample probe, the sampling train, the pilot probe, and the push probe (geoprobe) sampling truck.

The sample probe is 1-inch in diameter and is constructed of stainless steel with the bottom third perforated to allow LFG to be extracted. The probe is capped at the bottom to facilitate insertion into the landfill as well as to prevent debris from entering the probe and obstructing gas flow. At the top of the probe, a threaded cap with a sampling attachment connects the probe to the sampling train. The sample probe was long enough to extend to refuse at least 1.0 meter below the bottom of the landfill cover.

The sampling train consisted of the following components:

- A rotameter with a flow control valve capable of measuring a sample flow rate of 500 milliliters (mL)/minute (min) or less. The flow control valve is constructed of stainless steel.
- A sampling valve constructed of stainless steel.
- A pressure gauge. A digital manometer, capable of measuring pressure to within 0.1 inches (in.) Hg in the range of 0.1 to 99.9 in. Hg.
- A flow control valve, such as a needle valve, calibrated to provide a flow control of 250 mL/min.
- A sample tank/Tedlar bag. A stainless steel or aluminum canister (SUMMA canister), with a volume of 6 liters and equipped with a stainless steel sample tank valve. The Tedlar bags used for hydrogen sulfide analysis were light-shielded 1-liter bags.
- A purging/sampling pump capable of purging at a rate of 500 mL/min and suitable for sampling NMOCs and sulfur compounds.
- A Landtec GEM-500 gas analyzer capable of measuring oxygen, methane, carbon dioxide, and a nitrogen balance in percent, by volume.
- Three-way valves and associated tubing to direct flow during purging and sampling.

The pilot probe was constructed of tubing to withstand the impact of being driven into the landfill by the geoprobe unit. The pilot probe was capped on both ends and long enough to extend at least 1.0 meter below the bottom of the landfill cover.

The geoprobe unit was capable of driving the pilot probe and the sample probe into the landfill to the required depth(s), with a maximum capacity of approximately 20 feet.

5.5.1.2 *Field Sampling Procedures*

The sample tank (SUMMA) was evacuated and inspected for leaks prior to sampling. This procedure involved evacuating the sample tank to 10 mm Hg absolute pressure or less. The tank was allowed to sit for 60 minutes. The sample tank was acceptable if no changes in pressure were noted during this testing period. This procedure was done in the laboratory prior to fieldwork.

The sample probe installation involved using the geoprobe unit to drive the pilot probe at least 1.0 meter below the bottom of the landfill cover. The pilot probe was removed and the sample probe was driven into the hole left by the pilot probe. The sample probe was allowed to protrude about 0.3 meter above the landfill cover. Bentonite or native soil was then used to seal the space around the sampling probe. A sampling probe cap was placed in order to prepare the probe for sample collection.

Prior to sample collection, the purged gas stream was measured on-site with a field-calibrated GEM-500 gas analyzer and a hydrogen sulfide detector. Results of the field screening are presented in Table 5.6.

During sample collection, the rotameter valve and 3-way valves were opened to allow the pump to evacuate at least two sample probe volumes from the system at a flow rate of 500 mL/min or less. After the purge was completed, the rotameter valve was closed, the pump was turned off, and purge time, volume, and flow rate were recorded.

Gas quality was checked by opening the rotameter valve and three-way valves to allow the GEM-500 gas analyzer to measure percent by volume of oxygen, carbon dioxide, methane, and a nitrogen balance.

A second gas sample was collected by activating the pump and taking a 1-liter sample at a pumping rate of 250 mL/min. Flow rate, time, and drop in vacuum were recorded, and the sample was collected in a Tedlar bag for analysis of sulfur compounds.

A third and final gas sample was collected by opening the rotameter valve, three-way valves and sample tank valve. A 1-liter sample was taken at a flow rate of 250 mL/min. The needle valve provided a calibrated flow rate of 250 mL/min. Flow rate, time, and drop in vacuum in the SUMMA were recorded. The sample was analyzed for NMOCs.

Composite sampling was used during the sampling process as stated in 40 CFR 60.754(a)(3). By using composite sampling, a 1-liter sample was taken from each sample location, up to a maximum of five locations. Separate composites were collected of the LFG and SUR samples. Five 1-liter samples were collected in a 6-liter SUMMA canister, thereby assuring a residual vacuum in the canister. For NMOC samples, a 1-liter sample was established when a vacuum drop of 5 in. Hg was observed in the canister. For sulfur compound samples, the pumping flow rate was used to determine the amount of sample collected. Both flow rate and vacuum drop were used to check that equal volume samples were taken at each sample location. The sample probe was then removed and the hole was backfilled with cover material.

5.5.1.3 Sampling Analysis

Composite samples collected in the SUMMA canisters were sent to Severn Trent Laboratories (STL) in Santa Ana, California and analyzed for NMOCs using U.S. EPA Method 25C. Samples were also analyzed for hazardous air pollutants (HAPs) using U.S. EPA Method TO-15, and for fixed gases (methane, oxygen, carbon dioxide, and nitrogen) by American Society for Testing and Materials (ASTM) Method 1945. The samples were analyzed in duplicate to assure quality control and quality assurance. Tedlar bag samples were analyzed for sulfur compounds using

EPA Method 15/16. Landfill gas field sampling forms, which document sampling procedures, are provided in Appendix 5.6.

5.5.1.4 Sampling Results

The laboratory results indicated that the LFG samples contain methane, carbon dioxide, oxygen, and nitrogen as the main constituents. Trace amounts of the following toxic air contaminants (TACs) and other VOCs were also found in the LFG samples:

- Ethane
- Hydrogen Sulfide
- 1,2-Dichlorobenzene
- 1,4-Dichlorobenzene
- Methyl Ethyl Ketone (MEK)
- Acetone
- Chlorobenzene
- Chlorodifluoromethane
- Dichlorodifluoromethane
- Dichlorofluoromethane
- Ethylbenzene
- Xylenes
- Butane
- Hexane
- Pentane
- Propane
- Trichloroethene
- Vinyl Chloride

In addition, the average NMOC concentration for the LFG samples was approximately 485 parts per million (ppm) as methane. Analytical results of the LFG samples are presented in Table 5.7. Laboratory reports and chain-of-custody documentation are provided in Appendix 5.7.

5.5.2 Near-Surface Soil Vapor Sampling and Analysis

Near-surface soil vapor samples (SUR) were collected at the same location as the LFG sampling. These samples were used to identify and quantify the VOC concentrations within the cover soils of the Mission Bay Landfill for purposes of determining an attenuation factor to relate the estimated generation to the actual emissions through the cover of the Mission Bay Landfill.

After the raw LFG sample was collected, the sample probe was removed and the hole backfilled. A second sample probe was then inserted adjacent to the LFG sampling location using the geoprobe unit. The shallow soil vapor sampling followed the same procedure as the LFG sampling. Soil vapor samples were collected at a depth of 3 to

4 feet below ground surface (bgs) at the locations coincident with the raw LFG sampling locations.

Near-surface soil vapor was extracted and screened on-site with a GEM-500 gas analyzer, a flame ionization detector (FID), and a hydrogen sulfide detector. The FID was calibrated to methane, in order to detect total organic compounds (TOC) as methane. Results of the field screening are presented in Table 5.8.

Following field screening, samples collected were composited into stainless steel SUMMA canisters (five 1-liter samples per 6-liter canister) for chemical analysis. Composited soil vapor samples were analyzed for NMOCs using EPA Method 25C, HAPs using EPA Method TO-15, permanent gases (nitrogen, oxygen, methane, and carbon dioxide) using ASTM 1945, and sulfur compounds using EPA Method 15/16. Landfill gas field sampling forms, which document sampling procedures, are provided in Appendix 5.6.

5.5.2.1 *Near-Surface Soil Vapor Sampling Results*

The laboratory results indicated that the SUR samples contain methane, carbon dioxide, oxygen, and nitrogen as the main constituents. Trace amounts of the following TACs and other VOCs were also found in the SUR samples:

- Ethane
- Hydrogen Sulfide
- 1,2-Dichlorobenzene
- 1,4-Dichlorobenzene
- Methyl Ethyl Ketone (MEK)
- 2-Propanol
- Acetone
- Bromodichloromethane
- Chlorobenzene
- Chlorodifluoromethane
- Chloroform
- Dichlorodifluoromethane
- Dichlorofluoromethane
- Ethanol
- Ethylbenzene
- Xylenes
- Butane
- Hexane
- Pentane
- Propane
- Trichloroethene
- Vinyl Chloride

In addition, the average NMOC concentration for the samples was approximately 140 ppm as methane. Analytical results of the SUR samples are presented in Table 5.7. Laboratory Reports and Chain of Custody documentation are provided in Appendix 5.7.

5.5.3 Additional Landfill Gas Sampling

On July 21, 2004 14 additional landfill gas samples were collected at the Site by SCS and H&P to produce additional analytical data in areas of the Site that were reported to have landfill gas samples with elevated concentrations of COPCs during the previous landfill gas sampling completed by SCS. Landfill gas samples were collected at 14 locations from a sample probe driven into the ground by a hydraulic truck-mounted drill rig operated by H&P, or by hand when necessary. The sample was typically collected from within landfill material, generally targeting a minimum depth of 1.0 meter below the bottom of the landfill cover. The soil vapor samples were immediately transferred to a state-accredited on-site mobile laboratory provided by H&P for analysis for VOCs in general accordance with EPA Method 8260B.

5.5.3.1 Additional Landfill Gas Sampling Results

Trace amounts of the following TACs were also found in the LFG samples:

- Benzene
- Ethylbenzene
- Freon 113
- Vinyl Chloride

Analytical results of the additional LFG samples are presented in Table 5.9. Laboratory Reports and Chain-of-Custody documentation are provided in Appendix 5.7.

5.5.4 Ambient Air Sampling and Analysis

In general accordance with SCAQMD Rule 1150.1, the APCD collected ambient air samples on April 14, April 18, and May 3, 2004 at the landfill property boundary from both an upwind and downwind sampler sited to provide good meteorological exposure to the predominant offshore (drainage land breeze) and onshore (sea breeze) wind flow patterns. In addition, an ambient air sample was collected at the center of the Site. A copy of the APCD's report, dated July 7, 2004, is provided in Appendix 5.8.

5.5.4.1 Sampling Conditions

Ambient air sampling was conducted during typical meteorological conditions, representative for the season, with wind speeds of 2 miles per hour (mph) or less, and when onshore sea breezes occurred with wind speeds of 10 mph or less. Wind data

from the downtown San Diego air monitoring site was used because of its close proximity to the landfill. The wind conditions during sampling are summarized in the APCD's report (Appendix 5.8).

5.5.4.2 *Sampling Equipment*

The APCD conducted the sampling and analyses consistent with their current protocols. The ambient air sampling unit consists of a fused silica-coated stainless steel sample canister with a fused silica-coated passive air sampling kit, and a 24-hour clock timer to shut off the sampler at the end of the 24-hour sampling period.

5.5.4.3 *Ambient Air Sampling Results*

Results from the laboratory analysis indicated that only trace concentrations of toxic compounds were detected. The APCD concluded that localized hot spots of toxic compounds did not exist at the surface of the landfill and that trace concentrations of air pollutants detected at Mission Bay landfill sampling locations are representative of normal background ambient levels for this area of the county. The results of the sampling are presented in the APCD's report.

5.5.5 Surface Emissions Monitoring

On June 8, 2004, SCS performed integrated near-surface emissions monitoring on the areas with high field screening readings to assess the integrity of the landfill cover as an effective gas migration barrier. Each of the 50 grids were individually assessed for high field screen readings based on the sampling that was conducted during the raw LFG and near-surface soil vapor investigation. In general, areas with the highest readings from the near-surface soil vapor screening were chosen as areas to collect samples using the integrated surface sampling method since these areas would be most likely to have emissions from the surface of the landfill. For completely paved grid locations with high near-surface LFG concentrations, (e.g., grids A2, A3, and A4), the immediately adjacent unpaved areas were sampled (e.g., portions of grids A1, B1, B2, B3, and B4).

The monitoring of integrated surface emissions was completed in general accordance with instantaneous and integrated surface monitoring protocols set forth by the SCAQMD Rule 1150.1. A copy of these procedures is included in Appendix 5.9. In general accordance with SCAQMD Rule 1150.1, an integrated sample collection area of 50,000 square feet was established. Each of the 2.3-acre grids (approx. 100,000 square feet) designated for surface sampling (A1 and B1 through B4, I1, J2, L2, N1, and N3) was divided into two, 50,000-square-foot grids, with one sample collected from each area chosen. Portions of each grid that were paved were not sampled (e.g., one sample was collected from grid L2 since 50% is paved). The two samples collected from each grid (where applicable) were composited in the laboratory prior to analysis, as indicated in the chain of custody which is found in Appendix 5.7.

A total of six samples were collected for analysis at the following grid locations (Figure 5.2):

- Grids A1, B1, B2, B3, and B4 (partial grid locations due to paved areas)
- Grid I1 (only one sample collected due to paved areas)
- Grid J2 (composite of samples J2a and J2b)
- Grid L2 (only one sample collected due to paved areas)
- Grid N1 (composite of samples N1a and N1b)
- Grid N3 (composite of samples N3a and N3b)

The instantaneous surface emissions samples were analyzed for NMOCs using EPA Method 25C, VOCs using EPA TO-15, and sulfur compounds (including hydrogen sulfide) using EPA Method 15/16. This allowed for a direct comparison of collected data (raw LFG, near surface soil vapor, and surface emissions).

5.5.5.1 Surface Emissions Monitoring Results

The laboratory results indicated that the air above the surface of the landfill has a typical composition of oxygen and nitrogen and some carbon dioxide. Trace VOCs found in some of the samples included the following:

- 2-Propanol
- Acetone
- Carbon Disulfide
- Chloromethane
- Dichlorodifluoromethane
- Ethanol
- Ethylbenzene
- Xylenes
- Methylene Chloride
- Propane

Analytical results of the surface emission samples are presented in Table 5.7. Laboratory reports and chain-of-custody documentation are provided in Appendix 5.7.

5.5.6 LFG Generation Modeling

LFG generation estimates for the Mission Bay Landfill were developed using the EPA's LFG generation model (LANDGEM, Pelt et al, 1998) and actual methane gas concentrations reported from analytical data collected from the raw LFG samples taken from the Mission Bay Landfill.

Inputs for the EPA model included the estimates of in-place refuse amounts, which were placed during the operational period of the landfill (1952 to 1959), the ultimate methane generation potential ("Lo" value) of 170 m³/Mg, and a refuse decay

coefficient (“k” value) of 0.05. Refuse data was derived from previous investigations including a site assessment plan prepared for the City of San Diego by Woodward-Clyde Consultants on August 22, 1983, historical data review, as well as information collected by SCS. Default “Lo” and “k” values were derived from the EPA’s Compilation of Air Pollutant Emission Factors (AP-42), Section 2.4 on landfills and/or from SCS’ own database of factors derived from empirical studies of LFG recovery data of over 300 landfills, including over 75 in Southern California. Landfill gas generation estimates were used in the exposure assessment portion of the health risk assessment. The results of the model indicate that the highest LFG generation rate occurred in 1960 with a rate of 996 cubic feet per minute (cfm). The results of the LFG generation model are presented in Table 5.10. A more detailed explanation of the LFG generation modeling is included in Appendix 8.6 and in the human health risk assessment (Section 8).

5.6 Biological Resources Survey Fieldwork

A biologist with Merkel & Associates of San Diego, California, who has local Mission Bay-specific experience, conducted a field survey of ecological habitats and potential ecological receptors. Both flora and fauna were evaluated. The survey was preceded by a literature review of documents specific to the project area.

The purpose of the biological resources survey was to directly support the ecological scoping assessment described in Section 9. Specific species of flora and fauna were identified and the health of their habitat was evaluated. A copy of the Biological Resources Report is provided in Appendix 5.3 of this Report.

5.7 Soil and Groundwater Sampling from Soil Borings

5.7.1 Soil Boring Program

On June 16 and 17, 2004, August 9 and 10, 2004, and October 13 and 14, 2004 a total of 18 soil borings were advanced at the Site for the collection of soil and/or groundwater samples. Soil borings B3, B4, B5, B8, and B11 were advanced for soil characterization and landfill extent delineation only, therefore no soil or groundwater samples were collected for chemical analysis. The remaining soil borings (B1, B2, B6, B7, B9, B10, B10A, B12, B12A, B13, B14, B15, B16, B17, and B18) were sampled for soil and/or groundwater for chemical analysis. The location of the soil borings are depicted in Figure 5.3.

The purpose of the soil boring investigation was to expand upon the available data set, to aid in delineating/verifying the extent of the landfill, to assess the extent of hydraulic fill (soil cover), and to evaluate the existing contaminants in soil, both in close proximity to the surface and at depth.

Three additional borings (B14, B16, and B17) were drilled in features of concern that were discovered during our initial investigative work including the geophysical, LFG,

and historical studies (i.e., one possible “pond” was interpreted to be located on the 35-acre parcel).

A direct-push truck-mounted drilling rig was used to advance soil borings B1 through B16 in order to verify/delineate the landfill boundary in areas with limited data. The sampling method provided for minimal disruption to landfill waste, generated a minimal volume of drill cuttings, and provided a safer environment for workers in the exclusion zone at a lower cost than other conventional drilling methods. Due to the presence of surficial soils composed of uncohesive sands and silts in a majority of the 35-acre parcel portion of the Site (east of the intersection of Sea World Drive and Friars Road) it was inaccessible to heavy, rubber-tired vehicles like the direct-push drill rig used to advance soil borings B1 through B16. A track-mounted limited access drill rig supplied by West Hazmat Drilling Corporation was utilized to advance soil borings B17 and B18.

5.7.2 Soil Sampling Methodology and Guidance

The 2004 Site Assessment and Mitigation (SAM) Manual, which provides guidance for standard operating procedures (SOPs) for sampling, as well as internal SOPs, were followed during this assessment.

A qualified professional under the direct supervision of a professional geologist was on the Site to observe the drilling activity and describe collected soil samples in general accordance with the Unified Soil Classification System. Soil samples were characterized for the soil type and landfill waste, if present, and inspected for any obvious visual or olfactory indications of contaminants, and the presence of volatile organic compound vapors (detected by field screening with a photoionization detector). A soil boring log describing the observed soils and the contents of landfill waste, if encountered, was prepared for each boring advanced at the Site. Soil boring logs are included as Appendix 5.10.

Soil samples were collected in clear acetate sleeves if the soil boring was completed with a direct-push drill rig and soil samples were collected in either cylindrical stainless steel sleeves or glass jars if the boring was completed with a hollow-stem auger drill rig. The ends of the selected sections of the stainless and acetate sample sleeves were covered with Teflon™ sheeting, and tightly closed with end caps for handling activities. Chain-of-custody procedures were implemented for sample tracking.

Sampling equipment was cleaned between sampling events with a cleaning process consisting of a water-Alconox™ solution wash, two tap water rinses, and a final spray rinse with deionized water. This procedure was implemented between borings and sampling events and is intended to minimize the potential for cross-contamination between samples and obtaining a false positive result for soil samples analyzed. All soil borings were backfilled with hydrated bentonite chips and capped with black-dyed concrete, where appropriate.

Table 5.11: Soil Borings Location Rationale

Soil Boring(s) Designation	Location (Figure 5.3)	Rationale/Reasoning
B5, B6, B7, B8, B9	Western landfill delineation	Further assessment was warranted at the western boundary of the landfill, particularly between the former Sea World Drive and the existing Sea World Drive. These borings aided in the delineation of the presence or absence of waste (particularly considering the approximate locations of trenches excavated for refuse burial east of this area), identified current soil and groundwater conditions, and allowed for chemical characterization of the soil and groundwater.
B1, B2, B3, B4, B10, B11, B12, B13	Northern landfill delineation	These borings aided in the delineation of the presence or absence of waste at the northern boundary of the landfill, identified current soil and groundwater conditions, and allowed for chemical characterization of the soil and groundwater. They also provided data that aided in the placement of proposed monitoring wells.
B15 and B18	Eastern landfill delineation	These borings aided in the delineation of the presence or absence of waste (particularly considering the approximate locations of trenches excavated for refuse burial west of this area), identified current soil and groundwater conditions, and allowed for chemical characterization of the soil and groundwater.
B14, B16, B17	Within interpreted landfill extent	These borings aided in the delineation of the presence or absence of waste and provided physical and chemical characterization in the immediate vicinity of recognized former features of potential concern including what appeared to be "ponds."

5.7.3 Grab Groundwater Sampling Methodology and Guidance

A groundwater sample was collected from each of the borings that were targeted for chemical analysis (B1, B2, B6, B7, B9, B10A, B12A, B13, B14, B15, B16, B17, and B18), with the use of a discrete groundwater sampling probe such as a Hydropunch™ (from the soil borings completed with a direct-push drill rig) or a temporary well (from the soil borings completed with an auger drill rig). Subsequent to the completion of the boreholes advanced with an auger rig (B17 and B18), a temporary, 1-inch diameter, PVC well constructed with a screened interval of 15-feet was inserted into the borehole after extracting the augers. Before collecting the groundwater samples, groundwater was purged from inside the temporary wells until it was witnessed to be relatively free of entrained particles. The groundwater sample was then collected with a peristaltic pump and dedicated, precleaned disposable polyethylene tubing or with a clean disposable bailer. Please note that soil borings

B10A and B12A were completed directly adjacent to soil borings B10 and B12, respectively. Soil borings B10A and B12A were advanced on August 10, 2004 for the collection of grab groundwater samples only because insufficient water was present to provide a complete groundwater sample the previous day at boring locations B10 and B12.

As required by San Diego County guidelines, precleaned rods and augers were used to minimize the likelihood of cross-contaminating a given boring and to minimize the potential for a false positive in the groundwater samples analyzed.

The following table provides the location and rationale for each soil boring and in situ groundwater analysis.

5.7.4 Results of Soil Samples Collected from Soil Borings

Twenty-four soil samples collected during the advancement of the 18 soil borings completed at the Site were selected for laboratory analysis (Table 5.12). All 24 samples were analyzed for SVOCs in general accordance with EPA Method 8270C and for Title 22 Metals in general accordance with EPA Method 6010B/7470A. Six of the 24 samples were also analyzed for hexavalent chromium in general accordance with EPA Method 7199.

None of the analyzed soil borings samples were reported to contain detectable concentrations of SVOCs.

The reported concentrations of Title 22 Metals in soil samples collected from the soil borings were compared to the California Human Health Screening Levels (CHHSLs) for soil with commercial/industrial land use. All arsenic detections in soil exceed the arsenic CHHSL. However, the CHHSL for arsenic is extremely low (0.24 milligrams per kilogram [mg/kg]), even below the detection limit for arsenic of 0.25 mg/kg. Furthermore, natural background concentrations of arsenic in California range from 0.59 to 11 mg/kg, with an arithmetic mean concentration of 3.5 mg/kg (USEPA, 2005). Thus, even naturally occurring background concentrations of arsenic significantly exceed the CHHSL. Both U.S. EPA and Cal-EPA policy is to not require cleanup to below natural background levels. Therefore, arsenic soil concentrations above the CHHSL but within the range of natural background would not be expected to require remediation. Arsenic concentrations significantly above background, on the other hand, may present health or ecological risks. Potential risks associated with high arsenic soil concentrations were evaluated in the health and ecological risk assessments presented in Sections 8 and 9, respectively. No other exceedances of the remaining analyte CHHSLs were observed. Please refer to Section 8 for an evaluation of the human health risks associated with the soil samples collected from the soil borings at the Site.

The reported concentrations of hexavalent chromium in soil samples collected from soil borings ranged from below laboratory detection limits (<0.100 mg/kg) to 0.21

mg/kg in soil sample B18-20'. Please refer to Figure 5.4 for a Site map showing soil boring soil sample analytical results for metals and Figure 5.5 for a Site map showing soil boring sample analytical results for VOCs and SVOCs. A copy of the soil boring laboratory analytical data is provided in Appendix 5.11.

5.7.5 Results of Groundwater Samples Collected from Soil Borings

Thirteen groundwater samples were collected for laboratory analysis from soil borings completed at the Site (Table 5.13). All 13 samples were analyzed for VOCs (EPA Method 8260B), SVOCs (EPA Method 8270C), hexavalent chromium (EPA Method 7199, 2), specific conductance (EPA Method 120.1), hardness (EPA Method 130.2), pH (EPA Method 150.1), total dissolved solids (TDS) (EPA Method 160.1); chloride, fluoride, nitrate, and sulfate (EPA Method 300); and alkalinity, bicarbonate, carbonate, and hydroxide (EPA Method 310.1).

Benzene, chlorobenzene, ethylbenzene, 1,4-dichlorobenzene, isopropylbenzene, naphthalene, 1,2,4-trimethylbenzene, o-xylene, m-&p-xylenes were the only VOC analytes detected above the laboratory detection limits (1.0 to 2.0 micrograms per liter [$\mu\text{g/L}$]) in the soil boring groundwater samples. Two SVOC analytes (bis[2-ethylhexyl] phthalate and pentachlorophenol) were detected above the laboratory detection limits (10.0 and 1.0 $\mu\text{g/L}$, respectively) in the soil boring groundwater samples.

The reported results of the soil boring groundwater sample analysis were compared to three specified water quality criteria in Table 5.13. The three criteria are as follows: 1) Office of Environmental Health Hazard Assessment (OEHHA) Public Health Goals (PHGs) for Drinking Water, 2) California State Water Resources Control Board, Ocean Plan: 6-month median, and 3) United States Environmental Protection Agency (U.S. EPA) Region 9 Preliminary Remediation Goals (PRG) for Tap Water. Please note that these water quality criteria have been selected for comparison with the reported concentrations as a tool in the analysis of groundwater conditions at the Site and are not enforceable regulatory requirements. Reported concentrations were compared to the most stringent water quality criterion and the concentration was boldfaced in the table if an exceedance was observed.

Groundwater samples collected from soil borings B1, B14, B16, and B17 were observed to have detectable concentrations of benzene exceeding the PHG (0.15 $\mu\text{g/L}$). The remaining nine groundwater samples collected from the soil borings had no benzene reported above a laboratory detection limit (1.0 $\mu\text{g/L}$), which is in excess of the most stringent water quality screening criterion (PHG) of 0.15 $\mu\text{g/L}$. Groundwater samples collected from soil borings B1, B10A, B14, B16, B17, and B18 were observed to have exceedances of the PRG for 1,4-dichlorobenzene (0.50 $\mu\text{g/L}$). The remaining seven groundwater samples collected from the soil borings were reported with a laboratory detection limit (1.0 $\mu\text{g/L}$) for 1,4-dichlorobenzene which is in excess of the most stringent water quality screening criterion (PRG) of 0.50 $\mu\text{g/L}$.

Groundwater samples collected from soil borings B7 and B16 were observed to have exceedances of the Ocean Plan criterion for bis(2-ethylhexyl)phthalate (3.5 µg/L). The remaining 11 groundwater samples collected from the soil borings were reported with a laboratory detection limit (10.0 µg/L) for bis(2-ethylhexyl)phthalate which is in excess of the most stringent water quality screening criterion (Ocean Plan) of 3.5 µg/L. Groundwater samples collected from soil borings B10A and B17 were observed to have exceedances of the PHG for pentachlorophenol (0.4 µg/L). The remaining 11 groundwater samples collected from the soil borings were reported with a laboratory detection limit (1.0 µg/L) for pentachlorophenol which is in excess of the most stringent water quality screening criterion (PHG) of 0.4 µg/L.

Groundwater samples collected from the soil borings were reported to contain concentrations of hexavalent chromium below the laboratory detection limit (1.0 and 5.0 µg/L). The groundwater samples reported with a detection limit of 5.0 µg/L for hexavalent chromium (B1, B2, B6, B7, and B9) are in excess of the most stringent corresponding water quality screening criteria (Ocean Plan) of 2.0 µg/L. No other exceedances of the remaining analyte water quality criteria were observed. Please refer to Sections 8 and 9 for an evaluation of the human health risks and ecological risks associated with the soil boring groundwater samples collected at the Site.

Please refer to Figure 5.6 for a Site map showing soil boring groundwater sample analytical results. A copy of the soil boring laboratory analytical data is provided in Appendix 5.11.

5.8 Surface Soil Sampling

It was recognized during the initial data review that soil analyses had not been conducted on surficial soils at the Site. On July 28, 2004 a total of 10 surface soil samples were collected from depths of 4 to 12 inches below ground surface. Seven of the samples (S1 through S4, S6, S8, and S10) were obtained within the currently depicted landfill boundary, and the other three surficial soil samples (S5, S7, and S9) were collected from soils north of the landfill (between the landfill boundary and Mission Bay), as depicted in Figure 5.7.

Soils at the prescribed sample collection depth for each sample location (S1 through S10) were collected with a decontaminated hand auger and drive sampler. Samples were either driven into stainless steel sleeves and capped with Teflon™ sheeting and plastic end caps or collected in soil sample jars. Three Encore™ soil sampling devices were also collected at each sample location to fulfill the laboratory's volume requirements for the VOC analysis.

5.8.1 Results of Surface Soil Samples

Ten surface (4 to 12 inches below grade) soil samples were collected at the Site for laboratory analysis (Table 5.14). All 10 samples were analyzed for VOCs in general accordance with EPA Method 8260B, SVOCs in general accordance with EPA Method 8270C, total cyanide in general accordance with EPA Method 9014, chlorinated herbicides in general accordance with EPA Method 8151A,

organochlorine pesticides in general accordance with EPA Method 8081A, polychlorinated biphenyls (PCBs) in general accordance with EPA Method 8082, Title 22 Metals in general accordance with EPA Method 6010B/7470A, and hexavalent chromium in general accordance with EPA Method 7199.

Acetone was the only VOC analyte detected (147 micrograms per kilogram [$\mu\text{g/kg}$] in sample S2-6") above the laboratory detection limit (50 $\mu\text{g/kg}$) in the surface soil samples. Two PAH analytes (benzo[b]fluoranthene and chrysene) were detected above the laboratory detection limits in one or more of the surface soil samples.

The reported concentrations of Title 22 Metals in the surface soil samples were compared to the California Human Health Screening Levels (CHHSLs) for soil with commercial/industrial land use. All arsenic detections in soil exceed the arsenic CHHSL. However, the CHHSL for arsenic is extremely low (0.24 mg/kg), even below the detection limit for arsenic of 0.25 mg/kg. Furthermore, natural background concentrations of arsenic in California range from 0.59 to 11 mg/kg, with an arithmetic mean concentration of 3.5 mg/kg (USEPA, 2005). Thus, even naturally occurring background concentrations of arsenic significantly exceed the CHHSL. Both U.S. EPA and Cal-EPA policy is to not require cleanup to below natural background levels. Therefore, arsenic soil concentrations above the CHHSL but within the range of natural background would not be expected to require remediation. Arsenic concentrations significantly above background, on the other hand, may present health or ecological risks. Potential risks associated with high arsenic soil concentrations were evaluated in the health and ecological risk assessments presented in Sections 8 and 9, respectively. No other exceedances of the remaining analyte CHHSLs were observed. Please refer to Section 8, *Health Risk Assessment* for an evaluation of the human health risks associated with the surface soil samples collected at the Site.

The reported concentrations of SVOCs, total cyanide, chlorinated herbicides, organochlorine pesticides, and PCBs were below the respective laboratory detection limits for all the surface soil samples. Please refer to Figure 5.7 for a Site map showing surface soil sample analytical results. A copy of the surface soil sample laboratory analytical data is provided in Appendix 5.12.

5.9 Sediment Sampling in Mission Bay and the San Diego River

The proposed sediment sampling for Mission Bay and the San Diego River adjacent to the Site included five sample locations (Sediment 1 through Sediment 5). Please refer to Figure 5.7 for the location of the sediment samples. The sediment sampling locations targeted areas that were deemed highly probable of facilitating contaminant egress from the Site due to the presence of stormwater conduit outfalls and/or vicinity to a recognized possible preferential pathway. While several of the previous sediment sample locations provided an understanding of the sediment contaminant load in the San Diego River and Mission Bay, the goals of this study were to supplement the previous data, provide confirmatory data, and target specific areas.

On August 3, 2004, five sediment samples were collected from depths of 0 to 6 inches, i.e., immediately below the surface, with a decontaminated drive sampler. Samples were driven into stainless steel sleeves and capped with Teflon™ sheeting and plastic end caps. Soil samples for VOC analysis were also collected in three Encore™ soil sampling devices at each sample location. Three of the sediment samples (Sediment 3 through Sediment 5) were collected from the surficial soils of the San Diego River flood basin deposits, adjacent to stormwater conduit outfalls. Sediment sample Sediment 1 was collected in the southern shore of the South Shores Boat Basin, and sediment sample Sediment 2 was collected from the southern shore of Mission Bay (east of the South Shores Boat Basin).

The purpose of analyzing for sediment chemical characteristics was to supplement and provide confirmation of the previous sediment data and, in the case of metals analyses, to use the data for a comparison between the landfill and estimated background concentrations.

The sediment sampling program that was conducted under RWQCB Order 85-78 was reportedly conducted according to the U.S. EPA test procedures described in 40 CFR, Part 16. The sediment sampling plan was conducted in general accordance with U.S. EPA guidance and general sampling protocols and guidance established in the SAM Manual.

Table 5.15: Sediment Sample Location Rationale

Sediment Sample Designation	Location (Figure 5.3)	Rationale/Reasoning
Sediment 1	Southern shore of South Shores boat basin as well as being in the vicinity of the former San Diego River channel	Collected for the chemical characterization of sediment within the boat basin and within the vicinity of the interpreted former San Diego River channel.
Sediment 2	Mission Bay	Collected for the chemical characterization of sediment within Mission Bay adjacent to the landfill.
Sediment 3	Adjacent to stormwater conduit outfalls in the flood basin of the San Diego River	Collected for the chemical characterization of sediment within the flood basin of the San Diego River to assess for the presence of contaminant transported off-site.
Sediment 4		
Sediment 5		

5.9.1 Results of Sediment Sampling

Five sediment samples were collected at the Site for laboratory analysis (Table 5.16). All five samples were analyzed for VOCs in general accordance with EPA Method 8260B, SVOCs in general accordance with EPA Method 8270C, total cyanide in general accordance with EPA Method 9014, chlorinated herbicides in general accordance with EPA Method 8151A, organochlorine pesticides in general accordance with EPA Method 8081A, polychlorinated biphenyls (PCBs) in general accordance with EPA Method 8082, Title 22 Metals in general accordance with EPA Method 6010B/7470A, and hexavalent chromium in general accordance with EPA Method 7199.

The reported concentrations of VOCs, SVOCs, total cyanide, chlorinated herbicides, and organochlorine pesticides were below the respective laboratory detection limits for all the sediment samples. Please refer to Figure 5.7 for a Site map showing sediment sample analytical results. A copy of the sediment sample laboratory analytical data is provided in Appendix 5.13.

Six PAH analytes (acenaphthene (<100 to 380 µg/kg), anthracene (<2 to 2 µg/kg), naphthalene (<50 to 71 µg/kg), fluoranthene (<5 to 30 µg/kg), phenanthrene (<4 to 40 µg/kg), and pyrene (<10 to 130 µg/kg) were detected in the sediment samples above the laboratory detection limits.

The reported concentrations of Title 22 Metals in soil samples collected from the soil borings were compared to the California Human Health Screening Levels (CHHSLs) for soil with commercial/industrial land use. All arsenic detections in sediment exceed the arsenic CHHSL. However, the CHHSL for arsenic is extremely low (0.24 mg/kg), even below the detection limit for arsenic of 0.25 mg/kg. Furthermore, natural background concentrations of arsenic in California range from 0.59 to 11 mg/kg, with an arithmetic mean concentration of 3.5 mg/kg (USEPA, 2005). Thus, even naturally occurring background concentrations of arsenic significantly exceed the CHHSL. Both U.S. EPA and Cal-EPA policy is not to require cleanup to below natural background levels. Therefore, arsenic soil concentrations above the CHHSL but within the range of natural background would not be expected to require remediation. Arsenic concentrations significantly above background, on the other hand, may present health or ecological risks. Potential risks associated with high arsenic soil concentrations were evaluated in the health and ecological risk assessments presented in Sections 8 and 9, respectively. No other exceedances of the remaining analyte CHHSLs were observed. Please refer to Section 8, *Health Risk Assessment* for an evaluation of the human health risks associated with the sediment samples collected at the Site.

5.10 Monitoring Well Installation

Four groundwater monitoring wells (SCS1 through SCS4) were installed at the Site on September 13 and 14, 2004. The rationale for the wells is listed in the table below.

Table 5.17: Monitoring Well Location Rationale

Monitoring Well ID	Depth of Well	Location (Figure 5.3)	Rationale
SCS1	33.49 feet	South of South Shores boat basin and within the interpreted former river bed where it intersects the South Shores boat basin	To assess groundwater conditions, including tidal monitoring, directly to the south of the boat basin. This well provided more information for a recognized data gap, more specifically assessing groundwater conditions in the likely area of highest hydraulic gradient, and a potential preferential pathway (within the former San Diego River bed).
SCS2	35.29 feet	East of boat basin	To assess groundwater conditions, including tidal monitoring, east of the boat basin. This well provided more information regarding groundwater conditions in an area previously uninvestigated and facilitated the observation of off-site groundwater migration.
SCS3	30.92 feet	Within the former river bed directly south of Sea World Drive	To assess groundwater conditions in the area where the landfill was first established and in the former river bed. This well provided more information to develop a better understanding of the groundwater system at the Site as it relates to differences in salinity and to assess groundwater conditions in a possible preferential pathway (including possible reverses in hydraulic gradient during extreme low tides).
SCS4	30.52 feet	South of South Shores boat basin and approximately 550 feet west of SCS1	To assess groundwater conditions, including tidal monitoring, to the immediately south of the boat basin. This well provided more information regarding groundwater conditions in an area previously uninvestigated and facilitate the observation of off-site groundwater migration.

The wells were drilled with a CME-75 drilling rig equipped with 8-inch hollow stem augers. The monitoring wells SCS1 through SCS4 were constructed with 2-inch-diameter polyvinyl chloride (PVC) casing, with the screened interval consisting of a 15-foot length of 0.010-inch slotted casing, depending on the specific conditions of the aquifer, extending approximately

10 feet below and 5 feet above the field-interpreted water table. Each of the four wells was also constructed with a 5-foot sump at the bottom of the screened interval comprised of unperforated 2-inch-diameter PVC casing per the RWQCB request. A grade 2/12 sand pack was placed around, and 2 feet above, the screened interval. A minimum of 3 feet of bentonite seal was placed and hydrated above the sand filter pack. The wells were completed as a bollard protected steel stickup surface completion constructed in a 3-foot-diameter concrete apron in general accordance with current SAM Manual guidelines. Copies of the boring logs and well construction details are provided as Appendix 5.10.

A staff geologist under the direct supervision of a State of California Professional Geologist was on the Site to observe the drilling activity and monitoring well construction, and describe collected soil samples in general accordance with the Unified Soil Classification System.

Twenty-three soil samples were collected with a split-spoon-type sampler. Soil samples were driven into decontaminated stainless steel tubes. The tubes were covered with Teflon™ sheeting, tightly closed with end caps, labeled, and submitted to a state-accredited laboratory for analysis. Chain-of-custody procedures were implemented for sample tracking. The soil samples from the monitoring wells were collected at the following depths/locations:

- Minimum of 5-foot intervals
- Interpreted significant changes in lithology
- Areas of discoloration or staining
- Interpreted bottom of hydraulic fill
- Interpreted capillary fringe
- Odors or elevated readings from field screening instruments
- At other depths as deemed appropriate by the on-site professional.

Pursuant to County of San Diego Department of Environmental Health (DEH) guidelines, the augers were either precleaned or steam cleaned, using a boiler-equipped pressure washer, on-site between soil borings to minimize the likelihood of cross-contaminating the borings and to minimize the potential for a false positive in the soil samples analyzed.

Soil cuttings, rinsate, or purged water were placed in Department of Transportation (DOT)-rated 55-gallon drums which were labeled and stored on-site in a secure area, pending receipt of analytical results and evaluation of disposal options.

The wells were surged to settle the sand pack, and developed to remove fines from the sand pack and well casings. All wells comprising the monitoring well network present at the Site were surveyed to facilitate accurate groundwater elevation measurements.

5.10.1 Results of Soil Samples Collected from Monitoring Wells

Twenty-three soil samples collected during the advancement of the four monitoring wells completed at the Site were selected for laboratory analysis (Table 5.18). All 23 samples were analyzed for SVOCs in general accordance with EPA Method 8270C and for Title 22 Metals in general accordance with EPA Method 6010B/7470A. Six

of the twenty-three samples were also analyzed for hexavalent chromium in general accordance with EPA Method 7199.

None of the analyzed soil samples were reported to contain detectable concentrations of SVOCs except bis(2-ethylhexyl)phthalate, which was detected in soil sample SCS1-5' at 586 mg/kg.

The reported concentrations of Title 22 Metals in soil samples collected from the soil borings were compared to the California Human Health Screening Levels (CHHSLs) for soil with commercial/industrial land use. All arsenic detections in soil exceed the arsenic CHHSL. However, the CHHSL for arsenic is extremely low (0.24 mg/kg), even below the detection limit for arsenic of 0.25 mg/kg. Furthermore, natural background concentrations of arsenic in California range from 0.59 to 11 mg/kg, with an arithmetic mean concentration of 3.5 mg/kg (USEPA, 2005). Thus, even naturally occurring background concentrations of arsenic significantly exceed the CHHSL. Both U.S. EPA and Cal-EPA policy is to not require cleanup to below natural background levels. Therefore, arsenic soil concentrations above the CHHSL but within the range of natural background would not be expected to require remediation. Arsenic concentrations significantly above background, on the other hand, may present health or ecological risks. Potential risks associated with high arsenic soil concentrations were evaluated in the health and ecological risk assessments presented in Sections 8 and 9, respectively. No other exceedances of the remaining analyte CHHSLs were observed. Please refer to the *Health Risk Assessment Report* for an evaluation of the human health risks associated with the surface soil samples collected at the Site.

The reported concentrations of hexavalent chromium in soil samples collected from soil borings ranged from below laboratory detection limits (<0.100 mg/kg) to 0.65 mg/kg in soil sample SCS3-20'. Please refer to Figures 5.4 and 5.5 for a Site map showing monitoring well soil sample analytical results. A copy of the monitoring well soil sample laboratory analytical data is included as Appendix 5.14.

5.11 Groundwater Stratification Study

In order to determine if a distinct freshwater/saltwater interface occurs within the groundwater regime beneath the Site, a groundwater stratification survey was completed. The presence of a freshwater/saltwater interface in an aquifer represents an immiscible zone where preferential flow and transport could occur. The presence of an interface can significantly affect the communication of groundwaters between Mission Bay and south of the landfill where the San Diego River contributes brackish water, because of preferential flow and transport within a stratified groundwater system. The only reported depth-specific water quality measurements designed to evaluate water quality stratification at the Site were performed on October 12, 1993 by Woodward-Clyde on surface water within the South Shores Boat Basin and Mission Bay. No previous investigations performed at the landfill addressed the specific data requirements of the groundwater stratification study outlined in this section.

On October 10 and 11, 2004, the groundwater stratification study was completed with a calibrated Horiba U22XD water quality meter capable of simultaneously measuring pH, dissolved oxygen, conductivity, salinity, total dissolved solids, temperature, turbidity, and oxidation reduction potential. Water parameter measurements were measured throughout the water column in each of the 11 groundwater wells (including the newly installed wells SCS1 through SCS4 and excluding MBW7) at the Site. The meter was slowly lowered through the water column in each well to minimize the disturbance to the equilibrium of water quality in each well. Measurements were recorded at 1-foot intervals, within each monitoring well casing, from the water surface to the bottom of the well. Two sets of measurements were obtained at the 11 wells: during a low tide and after a high tide to assess the potential for variations stemming from tidal influences.

Stratification logs and graphs depicting total dissolved solids (TDS) versus depth are provided in Appendix 5.15. In general, pH, conductivity, and TDS values increased with depth while temperature and dissolved oxygen decreased with depth. It was observed that a 2- to 8-foot-thick layer of buoyant, brackish groundwater is entering the Site from the San Diego River. This conclusion was based on the observation of salinity (represented as TDS) value fluctuations with depth. A majority of the graphs provided in Appendix 5.15 demonstrate the presence of a halocline with a marked salinity increase at the interface of buoyant brackish groundwater above denser hypersaline groundwater. This halocline may be controlling contaminant migration beneath the Site. Appendix 5.15 also contains a summary table listing well construction information, pump depth, and data from the tidal and stratification surveys conducted during this site assessment. The table also provides an approximate depth range for the halocline, which is a gradual transition in several of the wells.

5.12 Groundwater Elevation Tidal Influence Study

Measurements of the tidally influenced groundwater levels in 11 wells (MBW1, MBW2, MBW3, MBE4, MBW5, MBE6, MW10, SCS1, SCS2, SCS3, and SCS4) at the Site were collected during the fall of 2004. The measurements were obtained using submersible water level meters equipped with onboard computers (datalogging pressure transducers) capable of continuously recording groundwater levels within a monitoring well to measure the tidal variations. Manual measurements were obtained at MBW7 periodically throughout the tidal influence study using interface probes with a manufacturer's reported accuracy of ± 0.01 feet.

The tidal influence study was conducted from October 7, 2004 to November 10, 2004. Before placing transducers in each well a manual depth-to-water measurement was obtained using a decontaminated interface probe in order to provide a baseline groundwater depth value. This baseline groundwater depth reading was entered into each respective pressure transducer upon test initiation in order to equilibrate the collected data points with an observed manual measurement in the preferred output format. The pressure transducers were configured to collect a measurement every 10 minutes. One transducer capable of measuring air pressure was placed at surface elevation in a well estimated to reside in the most central location within the Site (SCS2). The purpose of this transducer was to document the

barometric pressure experienced at the Site throughout the entirety of the tidal influence study. At the conclusion of the tidal influence study, the data were downloaded from the onboard dataloggers within each of the transducers.

Groundwater level fluctuations occur within the landfill on a daily basis. There are a number of ways to analyze the water level data, typically either by analyzing specific time intervals or by calculating longer-term averages of the water levels over time. Tides are caused by gravitational forces between the moon (and secondarily the sun) and the Earth. The rise and fall of the tides can be predicted on the basis of the lunar and solar orbits. The primary influence is the moon, and the lunar orbit occurs every 24 hours and 50 minutes. One method used to process the data is by taking an average of all the water levels recorded in a 24:50 period. Successive averages calculated for consecutive sets of data are known as a moving average. The moving average does not produce a constant value, but instead will reveal long-term trends in the data independent of the lunar diurnal variations.

The time series data was analyzed to determine the short-term gradient changes that occur as a result of tidal influences by comparing the water level data between the wells. In addition, tidal predictions for the National Oceanic and Atmospheric Administration's (NOAA) Quivira Basin, Mission Bay tidal station location were used to assess the hydraulic gradient between the wells and Mission Bay. The occurrence of two substantial rainfall events during the completion of a groundwater elevation study provided data that demonstrates the propagation of a "flood pulse" traveling through the Site subsequent to each rainfall event.

Figure 5.8 depicts water levels that occurred on October 16, 2004 at 12:00 pm prior to increased flows, and ultimately flood flows, in the San Diego River. These are average pre-flood groundwater elevations observed at the Site. Three groundwater elevation maps depicting groundwater elevations at three times subsequent to the initial rainfall event were prepared and are included in Appendix 5.16. (These figures and Figure 5.8 reflect the time-averaged data from 12 hours and 25 minutes both before and after the actual time given.) Figure 5.9 shows the thickness of the flood pulse by depicting the difference in groundwater elevations recorded on October 28, 2004 and October 16, 2004.

5.13 Groundwater Sampling

Groundwater samples were collected on November 22 and 23, 2004 from all the monitoring wells at the Site (excluding MBW7) to evaluate for the presence of dissolved volatiles, semi-volatiles, trace metals, and general minerals. It should be noted that the groundwater sampling event happened subsequent to the flood events recorded at the Site during the month-long groundwater elevation study. Two separate methods of groundwater sampling were utilized in the groundwater analytical assessment and are discussed in the following section: 1) the methods developed by Battelle Pacific Northwest Laboratory (EPA Method 1669; EPA 821/R-96-008) were utilized for the sampling of groundwater for metals analysis and 2) low-flow sampling methodology (ASTM designation D6771-02) were used for collection of samples for all other analysis. The groundwater sampling activities were conducted on seven existing groundwater wells (excluding MBW7) and the four newly installed groundwater wells (SCS1 through SCS4).

5.13.1 Elevation

The monitoring wells were monitored and sampled in general accordance with DEH guidelines. Depth-to-groundwater measurements were taken using an oil-water interface probe with the manufacturer's reported accuracy of 0.01 of a foot. Each well was monitored for the presence of phase-separated hydrocarbons (PSH) (i.e., "free product").

5.13.2 Groundwater Sampling for Volatiles, Semi-Volatiles, Anions, and General Water Quality Characteristics

In an effort to obtain groundwater samples more representative of aquifer conditions, by reducing vertical mixing within the borehole and reducing the amount of purge water produced from the sampling event, low-flow sampling methodology (ASTM designation D6771-02) was performed on all the wells sampled at the Site. Water was removed from each well with the use of an existing dedicated bladder pump in conjunction with dedicated, non-reactive polyethylene tubing. The pump intake was positioned at approximately the mid-point of the length of the wetted screen. Water was purged from each well at flow rates conducive to each well's approximate sustainable yield. Water was pumped through a flow cell with an approximate operating volume of 350 milliliters (mL), containing a calibrated water quality meter capable of measuring pH, dissolved oxygen, conductivity, salinity, total dissolved solids, temperature, turbidity, and oxidation reduction potential. The water quality meter and associated low-flow cell were decontaminated before purging and sampling each well.

The following table summarizes the most recent SAM Manual stabilization criteria that were used as guidance when performing the groundwater sampling event.

Table 5.19: SAM Manual Stabilization Criteria for Groundwater Well Purging Prior to Sampling

Parameter	Most recent SAM Manual stabilization criteria (units)
pH	± 0.2 of reading
Dissolved Oxygen	± 0.2 (mg/L)
Conductivity	± 3 - 5% of reading
Temperature	± 3°C reading
Turbidity	± 10 % & < 50 (NTU)
Oxidation reduction potential	± 20 mV

Notes: mg/L = milligrams per liter
S/m = Siemens per meter
g/L = grams per liter
°C = degrees Celsius
NTU = Nephelometric Turbidity Units
mV = millivolts

Purging and groundwater sampling were performed in general accordance with DEH guidelines. Purge water generated during well development and sampling was disposed of at the supplied wastewater receiving receptacle located adjacent to the restroom facilities at Mission Bay Park.

Water quality measurements were obtained from the water quality meter each time that an approximate new low-flow-cell volume of groundwater was purged from the well. This length of time was calculated in the field by dividing the approximate operating flow cell volume (350 mL) by the current flow rate of the pump. After three stabilized consecutive water quality measurements, a groundwater sample was collected from each well by bypassing the flow cell and pumping the sample directly into appropriate laboratory-supplied containers. The samples were labeled and placed in an ice-packed cooler for transport under chain of custody to a state of California-accredited laboratory for analysis of COPC as listed in Table 5.5, other than metals. Copies of the groundwater sampling field forms are provided as Appendix 5.17.

5.13.3 Groundwater Sampling for Metals

Groundwater samples for metals analysis were collected on November 15 and 23, 2004. The methodology that was used was intended to minimize sample contamination and obtain samples in the cleanest manner practicable (EPA Method 1669; EPA 821/R-96-008). The objective was to reduce, to the greatest degree practicable, possible sample interferences associated with analysis of samples having a salt water matrix and the potential for introducing external contaminants (dust from the nearby freeway, or industrial activities, sampling equipment, well structures, etc.) and cross-contamination between wells. Because of the low levels of detection achievable by the analytical methods utilized ($\ll 1$ parts per billion [ppb]), very small amounts of contaminants can cause significant changes in the concentrations observed. The samples were handled as little as possible in the field to reduce the potential for external contamination; therefore, they were not filtered in the field. No preservatives were introduced to the samples in the field.

Three Quality Assurance/Quality Control (QA/QC) samples were collected during the assessment to evaluate potential sources of contamination from sampling, shipment, and laboratory equipment. One trip blank, one field blank, and one duplicate sample were obtained for the trace metals analyses. All samples were filtered by the laboratory before analysis using a 0.45-micron filter. Upon acceptance of the initial groundwater sample from monitoring well MBW1, the laboratory reported to SCS that the sample contained an unfilterable colloidal suspension. Well MBW1 was sampled a second time (on November 23) to attempt to retrieve a sample free of the colloidal suspension. The laboratory reported that the second groundwater sample from well MBW1 contained the colloidal suspension as well and the laboratory was instructed to analyze the unfiltered sample collected from well MBW1, which is why the laboratory reported this sample as MBW (Total).

Samples collected under protocol established in EPA Method 1669 were analyzed by Battelle Marine Science Laboratory (Battelle) in Sequim, Washington. The Trace Metals Group of Battelle provides private industry with state-of-the-art laboratory services and equipment and was chosen because it is an industry leader in ultra-trace-metal analyses, and was instrumental in the development of the EPA methodologies associated with these sensitive analyses (EPA Method series 1600). Battelle provided pre-cleaned sample bottles, shipping instructions, specific sample preservation, and the ultra-trace-metal analysis for this complex sampling procedure and methodology.

Battelle has analytical capabilities that can provide the detection of heavy metals in water at the part-per-trillion level, as well as the analysis for metals using the National Oceanic and Atmospheric Administration (NOAA) Status and Trends techniques and standard EPA Methods.

Battelle maintains a current QA management plan, and all data are validated by QA managers. QC is provided using National Institute Standards and Technology (NIST) references, matrix spikes, and duplicates, among others.

5.13.3.1 *Sample Handling*

The metals sampling methodology designed for ultra-low detection sampling for metals requires adherence to strict procedures and requires two people designated as “Clean Hands” and “Dirty Hands” to conduct the sampling. The analytical method employed for trace metals analysis of the groundwater samples is the new EPA low-detection (clean) method for trace metals in seawater (Method 1640). This method requires that several extra precautions be employed in preparation of sample containers and sample collection. These precautions helped to prevent introduction of contaminants into the water samples from exogenous sources such as dust, surface films on the water; contaminated substances on sample containers, collection devices, structures and plumbing fixtures; or the hands of sampling or analytical personnel.

5.13.3.2 *Sample Container Packets and Labeling*

Polyethylene sample containers were employed for sample collection and transport of the samples sent to Battelle. The sample containers and caps used for the clean sampling approach were specially precleaned by Battelle’s laboratory using an acid soak. After drying, the containers were capped and placed inside two sterile Ziploc™ bags to assemble individual sample packets for each sampling location. Waterproof labels were affixed to the outside of the container prior to placement in the bags. This sample packet configuration isolates individual samples from one another and contains any leaking water from the samples to prevent cross-contamination. Sample packets were placed in plastic insulated coolers for transport.

At the time of use, sample containers were labeled using a permanent marker. Sample designation, sampling date, and sampling time were noted on the sample container label by the “Clean Hands” designated staff.

5.13.3.3 *Sampling Personnel*

Water samples were collected by two people using clean collection techniques described in EPA Method 1664 (developed in part by Dr. Eric Crecelius, Battelle Pacific Northwest Division, Marine Sciences Laboratory [Battelle]). For purposes of sample collection, one individual was designated as the “Clean Hands” collector and the other was designated as the “Dirty Hands” collector for the duration of each sampling session. Both individuals wore latex gloves during collection. The “Dirty Hands” person and the “Clean Hands” person donned new, clean, individually packaged gloves at each collection site prior to contacting any sample containers or water. The “Dirty Hands” person touched only the outer Ziploc bag of the sample container packet during the process of extracting the sample container from the sample packet. The “Clean Hands” person was the only person to handle the inner bag and the sample container; this person opened and closed the inner bag of the sample container packet, removed, labeled, and opened the sample container, collected the sample, recapped the container, replaced the container in the inner Ziploc bag, and resealed the bag. The inner bag was never removed from inside the outer bag.

5.13.3.4 *Collection Procedures*

Samples were collected using the clean sampling technique described in Method 1669, modified for sample collection with a bailer in a manner described by Dr. Crecelius (personal communication).

Both people involved in sample collection used non-talc or “powder-free” gloves. All sampling materials and containers were placed downwind of the groundwater well being sampled. First, while wearing clean, non-talc gloves, the “Clean Hands” person opened the bag containing a clean bailer and attached a spooled non-metallic lowering line to the bailer. The “Clean Hands” person then donned another set of clean non-talc gloves. The “Dirty Hands” person then opened the outer bag and held it open so the “Clean Hands” person could reach the inner bag. The “Clean Hands” person then opened the inner bag, leaving it nested inside the outer bag, and removed the sterile sample container.

While the sample container was being labeled, the “Dirty Hands” person placed the sample bag packet into the cooler for temporary safekeeping, removed the special clean bailer, inserted it into the groundwater well and lowered it to the desired sampling depth. The “Dirty Hands” person then retrieved the bailer containing the groundwater sample. The “Clean Hands” person removed the cap of the sample container and placed the mouth of the container so that water could be released from the bailer into the sample container without contacting the sample container. The container was overfilled so that it was flushed and most of the air bubbles were expelled. The sample container was then recapped and placed back inside the inner Ziploc bag. The inner and outer bags were then resealed and the sample container packet was placed in a cooler chest for storage and shipping. During the entire

procedure, care was taken to avoid contact between the sampler's gloves or the sample containers and any surfaces or substances that could be contaminated. All materials used for sampling were disposed of subsequent to groundwater sample collection.

5.13.3.5 QA/QC Samples

The two types of QA/QC samples (field blanks and trip blanks) were collected during the metals analysis sampling event to evaluate potential sources of contamination. The purpose of the trip blank was to provide an assessment of potential contamination during transport of the sample containers to and from the lab. For this blank, a sample of reagent water packaged identically to the sample container packet was included in the shipment of sample containers from the lab. This sample accompanied the sample container packets and samples during the entire trip but remains bagged and unopened. Any contamination detected in this blank is assumed to have occurred during transit of the sample containers to and from the laboratory and represents transport contamination.

The purpose of the field blank was to provide an assessment of the potential for the collection procedure to contribute contamination. For this blank, a sample of reagent water included in the shipment of sample containers from the laboratory was poured from its shipping container into a clean unused bailer and then decanted into one of the sample containers sent by the laboratory using the same procedure as for the well samples. This transfer was completed at one of the monitoring wells that were sampled during the sampling event. Any contamination detected in this blank above that observed in the trip blank is assumed to have occurred during the sampling event and represents contamination due to sampling methodology.

5.13.3.6 Sample Holding and Shipment

The samples being analyzed for trace metals did not require fixation or refrigeration and holding times are in excess of 1 week. The samples were shipped by courier on the day of collection for next-day delivery. The groundwater samples were not filtered in the field; they were filtered in the laboratory because this reduced the likelihood of sampling contamination.

5.13.4 Results of Groundwater Samples Collected from Monitoring Wells

Eleven groundwater samples were collected for laboratory analysis from monitoring wells at the Site (Tables 5.20 and 5.21) on November 22 and 23, 2004. All 11 samples were analyzed for VOCs (EPA Method 8260B), SVOCs (EPA Method 8270C), hexavalent chromium (EPA Method 7199, 2), specific conductance (EPA Method 120.1), hardness (EPA Method 130.2), pH (EPA Method 150.1), TDS (EPA Method 160.1); chloride, fluoride, nitrate, and sulfate (EPA Method 300); and alkalinity, bicarbonate, carbonate, and hydroxide (EPA Method 310.1). All of the groundwater samples and two QA/QC samples (FB and TB) were analyzed for

mercury in general accordance with EPA Method 1631 and 16 other metals (beryllium, vanadium, chromium, cobalt, nickel, copper, zinc, arsenic, selenium, molybdenum, silver, cadmium, antimony, barium, thallium, and lead) in general accordance with EPA Method 1669/1640.

None of the monitoring well groundwater samples were reported to contain detectable concentrations of SVOCs. The reported concentrations of hexavalent chromium in monitoring well groundwater samples were below the laboratory detection limit (1.0 micrograms per liter [$\mu\text{g/L}$]).

The reported concentrations of arsenic ranged from 0.072 $\mu\text{g/L}$ in the duplicate sample collected from monitoring well SCS3 to 19.6 $\mu\text{g/L}$ in the sample collected from monitoring well MBE4. The reported concentration of cadmium ranged from 0.0131 $\mu\text{g/L}$ in the sample collected from monitoring well SCS4 to 0.347 $\mu\text{g/L}$ in the sample collected from monitoring well MBW5. The reported concentration of copper ranged from 0.122 $\mu\text{g/L}$ in the sample collected from monitoring well SCS3 to 21.8 $\mu\text{g/L}$ in the sample collected from monitoring well MBW1. The reported concentration of lead ranged from 0.0124 $\mu\text{g/L}$ in the sample collected from monitoring well MBE6 to 1.9 $\mu\text{g/L}$ in the sample collected from monitoring well MBW1. The reported concentration of zinc ranged from 2.12 $\mu\text{g/L}$ in the sample collected from monitoring well MBW2 to 163 $\mu\text{g/L}$ in the sample collected from monitoring well MBW1. The reported concentration of mercury ranged from 0.000423 $\mu\text{g/L}$ in the sample collected from monitoring well SCS3 to 0.109 $\mu\text{g/L}$ in the sample collected from monitoring well MBW1.

Specific conductance was reported to range from 42,400 (microsiemens per centimeter [$\mu\text{S/cm}$ or $\mu\text{mho/cm}$]) in the groundwater sample collected from monitoring well MBE6 to 111,000 $\mu\text{mho/cm}$ in the groundwater sample collected from monitoring well MBE4. Total dissolved solids concentrations (TDS) were reported to range from 28,500 milligrams per liter (mg/L) in the groundwater sample collected from monitoring well MBE6 to 82,300 mg/L in the groundwater sample collected from monitoring well MBE4. Sulfate concentrations were reported to range from 35.5 mg/L in the groundwater sample collected from monitoring well MBW2 to 4,340 mg/L in the groundwater sample collected from monitoring well MBE4. Please refer to Figures 5.4 and 5.5 for Site maps showing monitoring well groundwater sample analytical results. Copies of the groundwater sample laboratory analytical data are included as Appendix 5.18.

The reported results of the groundwater sample analysis were compared to three specified water quality criteria in Tables 5.20 and 5.21. The three criteria are as follows: 1) Office of Environmental Health Hazard Assessment (OEHHA) Public Health Goals (PHGs) for Drinking Water, 2) California State Water Resources Control Board, Ocean Plan: 6-month median, and 3) United States Environmental Protection Agency (U.S. EPA) Region 9 Preliminary Remediation Goals (PRGs) for Tap Water. Please note that these water quality criteria have been selected for comparison with the reported concentrations as a tool in the analysis of groundwater

conditions at the Site and are not enforceable regulatory requirements. Reported concentrations were compared to the most stringent water quality criterion and boldfaced in the table if an exceedance was observed.

Groundwater samples collected from the monitoring wells were reported to have concentrations of benzene below the laboratory detection limit (1.0 µg/L). The reported detection limit for benzene is in excess of the most stringent corresponding water quality screening criterion (PHG) of 0.15 µg/L. Methyl tertiary butyl ether (MTBE), cis-1,2-dichloroethene, and 1,4-dichlorobenzene were the only VOC analytes detected above the laboratory detection limits (1.0 and 2.0 µg/L) in the monitoring well groundwater samples. Groundwater samples collected from monitoring wells SCS1 and SCS4 were observed to have exceedances of the PRG for 1,4-dichlorobenzene (0.50 µg/L). The remaining nine groundwater samples collected from the monitoring wells were reported with a laboratory detection limit (1.0 µg/L) for 1,4-dichlorobenzene which is in excess of the most stringent water quality screening criterion (PRG) of 0.50 µg/L. The groundwater sample collected from monitoring well MBE6 was observed to have an exceedance of the PRG for MTBE (11 µg/L).

Groundwater samples collected from the monitoring wells were reported to have concentrations of hexavalent chromium below the laboratory detection limit (1.0 µg/L), which exceeds the most stringent corresponding water quality screening criterion (Ocean Plan) of 2.0 µg/L. The groundwater sample collected from the monitoring well MBE4 was observed to have an exceedance of the PRG for vanadium (36 µg/L). Groundwater samples collected from monitoring wells MBE4, MBW5, MW10, SCS2, and SCS4 were observed to have exceedances of the Ocean Plan for nickel (5.0 µg/L). Groundwater samples collected from monitoring wells MBW1 and MBE4 were observed to have exceedances of the Ocean Plan for copper (3.0 µg/L). Groundwater samples collected from monitoring wells MBW1, MBW5, MW10, SCS1, and SCS2 were observed to have exceedances of the Ocean Plan for zinc (20.0 µg/L). All of the groundwater samples collected from the monitoring wells were observed to have exceedances of the PHG for arsenic (0.004 µg/L). The groundwater sample collected from monitoring well MBW1 was observed to have an exceedance of the Ocean Plan for silver (0.7 µg/L). Groundwater samples collected from monitoring wells MBW1, MBE4, MBW5, and SCS2 were observed to have exceedances of the PHG for cadmium (0.070 µg/L). Groundwater samples collected from monitoring wells MBW1 and MBE4 were observed to have exceedances of the Ocean Plan for copper (3.0 µg/L). The groundwater sample collected from monitoring well SCS1 was observed to have an exceedance of the PHG for barium (2,000 µg/L). The groundwater sample collected from monitoring well MBW1 was observed to have an exceedance of the Ocean Plan for mercury (0.04 µg/L). No other exceedances of the remaining analyte water quality criteria were observed. Please refer to Sections 8 and 9 for an evaluation of the human health risks and ecological risks associated with the monitoring well groundwater samples collected at the Site.

5.13.5 Comparison of ULD (Battelle) and Conventional Sample Results

The analysis of groundwater and pore water samples using a laboratory methodology designed for high-salinity water (EPA Methods 1631 and 1669/1640) provided results with lower detection limits (ultra-low detection [ULD]) than previously requested analysis for groundwater samples collected at the Site. The lower detection limits allowed for a more reliable assessment of groundwater conditions at the Site. Comparison of reported analytical results for historical and recently collected groundwater samples with no detectable concentrations of metals suggests that those concentrations below the detection limit may be “false negatives.” The results of the analysis performed by Battelle indicated that detectable concentrations of all 17 metals (beryllium, vanadium, chromium, cobalt, nickel, copper, zinc, arsenic, selenium, molybdenum, silver, cadmium, antimony, barium, thallium, lead) are present in groundwater beneath the Site. This suggests that none of the seventeen metals present can be discounted and therefore removed from the list of COPCs at the Site. The reported concentrations of metal species from the analysis performed by Battelle in comparison to those from the conventional analysis were in general higher, except for selenium and thallium. The lower detection limits provided by the analysis performed by Battelle allowed for a more precise comparison of reported concentrations to the water quality criterion used for screening purposes. Should the Data Quality Objectives of the future groundwater sampling program require the most representative analytical results that are possible then the continuation of the groundwater sample analysis in accordance with EPA Methods 1631 and 1669/1640 are recommended. Table 5.22 presents the reported analytical results of the groundwater samples collected by EMCON on November 30, 2004 during the regular quarterly sampling of the wells. A copy of the analytical report for the groundwater samples collected on November 30, 2004 is provided as Appendix 5.19. Table 5.23 presents a comparison of the conventional metals analysis (EPA Methods 6010/6020) results to those of the ultra-low concentration metals analysis (EPA Method 1669/1640) results and the most stringent water quality criterion.

5.14 Survey of Monitoring Wells

On October 14, 2004, all 12 monitoring wells were surveyed by a licensed land surveyor (Hirsch & Company) for both vertical and horizontal control and to allow for an accurate estimate of groundwater elevation and gradient. The survey report is included in Appendix 5.20.

The previously reported top-of-casing elevations for the monitoring wells (measured in relation to the National Geodetic Vertical Datum of 1929 [NGVD29]) are approximately 2 feet lower than the top-of-casing elevations reported from the October 14, 2004 survey event (measured in relation to North American Vertical Datum of 1988 [NAVD88]). The elevation difference of the monitoring wells appears to be the result of the elevation difference of the older (NGVD29) and most recent (NAVD88) datums used to complete the survey events. The elevation difference of the two datums (approximately 2.22 feet) in the vicinity of the

Site was calculated using three GPS control points taken from the San Diego GPS Control Map (Record of Survey 14492).

5.15 Drive Point Installation (Within the South Shores Boat Basin and San Diego River Flood Basin)

Four temporary piezometers or drive points were installed at the Site in order to obtain pore water chemistry data and to evaluate vertical hydraulic gradients at locations adjacent to the landfill that are representative of the two Site boundaries that facilitate groundwater flow into and out of the Site. Pore water samples DP1 and DP2 were collected from drive points installed temporarily in the southern shore of the South Shores Boat Basin. Pore water samples DP3 and DP4 were collected from drive points temporarily installed in the surficial soils of the San Diego River flood basin, adjacent to stormwater conduit outfalls. An attempt was made to temporarily install two drive points in the southern shore of Mission Bay (east and west of the South Shores boat basin) although a number of factors prevented this. The presence of very low permeability silt at depths comparable with those accessible to the screened interval did not produce the required volumes of pore water during low tide conditions. Also, after many attempts the drive point encountered refusal, presumably on buried rip rap used for bank stabilization, at depths shallower than the depths required to assure proper placement of the screened interval. No previous studies performed at the landfill addressed the specific data requirements of this particular aspect of the investigation. The data obtained from completion of the drive point installation and subsequent measurements provided for a better understanding of groundwater discharge/recharge into Mission Bay and the San Diego River.

Each drive point consisted of a 1.5-inch-diameter rod connected to a drive point probe. The drive point probe has a pointed tip and contains a screened interval comprised of screened circular perforations to allow groundwater to enter the interior. The drive points were advanced by driving them using a slide hammer so that the top of the screened interval extended at least 2 to 3 feet below the top of grade. After advancing the drive points to the appropriate depth, water was evacuated from the interior of the drive point to remove surface water and allow for the groundwater elevation to equilibrate in the drive point. After equilibration of pore water inside the drive point was achieved, measurements of groundwater level inside the drive points and corresponding elevations of surface water outside the drive point were recorded to evaluate the vertical hydraulic gradients between groundwater beneath the sediments adjacent to the Site and water within Mission Bay or the San Diego River. Samples were also collected from within the drive points during low-tide conditions using a clean dedicated bailer and then decanted into laboratory-provided containers.

5.15.1 Results of Drive Point (Pore Water) Samples

Four pore water samples were collected for laboratory analysis from four temporary drive points installed at the Site (Tables 5.21 and 5.24). All four samples were analyzed for VOCs (EPA Method 8260B), SVOCs (EPA Method 8270C), hexavalent chromium (EPA Method 7199, 2), specific conductance (EPA Method 120.1),

hardness (EPA Method 130.2), pH (EPA Method 150.1), TDS (EPA Method 160.1); chloride, fluoride, nitrate, and sulfate (EPA Method 300); and alkalinity, bicarbonate, carbonate, and hydroxide (EPA Method 310.1). All four of the pore water samples were also analyzed for mercury in general accordance with EPA Method 1631 and 16 other metals (beryllium, vanadium, chromium, cobalt, nickel, copper, zinc, arsenic, selenium, molybdenum, silver, cadmium, antimony, barium, thallium, and lead) in general accordance with EPA Method 1669/1640.

None of the pore water samples were reported to contain detectable concentrations of VOCs and SVOCs. The reported concentrations of hexavalent chromium in monitoring well groundwater samples were below the laboratory detection limit (1.0 mg/L).

The reported concentrations of arsenic ranged from 0.105 µg/L in the pore water sample collected from drive point DP4 to 0.92 µg/L in the pore water sample collected from drive point DP3. The reported concentration of cadmium ranged from 0.0367 µg/L in the pore water sample collected from drive point DP4 to 0.27 µg/L in the pore water sample collected from drive point DP1. The reported concentration of copper ranged from 0.299 µg/L in the pore water sample collected from drive point DP2 to 1.03 µg/L in the pore water sample collected from drive point DP1. The reported concentration of lead ranged from below laboratory detection limit (0.009 µg/L) in the pore water sample collected from drive point DP4 to 0.0745 µg/L in the pore water sample collected from drive point DP3. The reported concentration of zinc ranged from 2.2 µg/L in the sample pore water sample collected from drive point DP2 to 429 µg/L in the pore water sample collected from drive point DP1. The reported concentration of mercury ranged from 0.000343 µg/L in the pore water sample collected from drive point DP1 to 0.000485 µg/L in the pore water sample collected from drive point DP4.

Specific conductance was reported to range from 52,200 µmho/cm in the pore water sample collected from drive point DP3 to 54,700 µmho/cm in the pore water sample collected from drive point DP1. Total dissolved solids concentrations (TDS) were reported to range from 31,600 mg/L in the pore water sample collected from drive point DP2 to 36,000 mg/L in the pore water sample collected from drive point DP1. Sulfate concentrations were reported to range from 2,630 mg/L in the pore water sample collected from drive point DP2 to 2,790 mg/L in the pore water sample collected from drive point DP1. Tables 5.21 and 5.24 present reported analytical results of the pore water samples collected from the four drive points. Please refer to Figure 5.6 for a Site map showing drive point pore water sample analytical results. A copy of the pore water laboratory analytical data is included as Appendix 5.18.

The reported results of the pore water sample metals analysis were compared to three specified water quality criteria in Tables 5.21 and 5.24. The three criteria are as follows: 1) Office of Environmental Health Hazard Assessment (OEHHA) Public Health Goals (PHGs) for Drinking Water, 2) California State Water Resources Control Board, Ocean Plan: 6-month median, and 3) United States Environmental

Protection Agency (U.S. EPA) Region 9 Preliminary Remediation Goals (PRGs) for Tap Water. Please note that these water quality criteria have been selected for comparison with the reported concentrations as a tool in the analysis of groundwater conditions at the Site and are not enforceable regulatory requirements. Reported concentrations were compared to the most stringent water quality criterion and boldfaced in the table if an exceedance was observed.

The pore water sample collected from drive point DP3 was observed to have an exceedance of the Ocean Plan for nickel (5.0 µg/L). The pore water samples collected from drive points DP1, DP3, and DP4 were observed to exceed the Ocean Plan for zinc (20.0 µg/L). The pore water samples collected from the drive points were observed to exceed the PHG for arsenic (0.004 µg/L). The pore water sample collected from drive point DP1 was observed to have an exceedance of the PHG for cadmium (0.070 µg/L). Pore water samples collected from the drive points were reported to have concentrations of benzene below the laboratory detection limit (1.0 µg/L), which is in excess of the most stringent corresponding water quality screening criterion (PHG) of 0.15 µg/L. Pore water samples collected from the drive points were reported to have concentrations of 1-4, dichlorobenzene below the laboratory detection limit (1.0 µg/L), which is in excess of the most stringent corresponding water quality screening criterion (PRG) of 0.5 µg/L. Pore water samples collected from the drive points were reported to have concentrations of hexavalent chromium below the laboratory detection limit (1.0 µg/L), which is less than the most stringent corresponding water quality screening criterion (Ocean Plan) of 2.0 µg/L.

5.15.2 Observed Hydraulic Gradients

Sampling was conducted during an outgoing tidal cycle to obtain water samples representative of groundwater discharging from the site into adjacent surface water bodies. The difference in the water levels observed in the drive points versus the surrounding surface water is indicative of the relative vertical hydraulic gradient at that point. The pore water measurements taken from the drive points (Section 5.15) advanced within the sediment comprising the San Diego River flood basin to the south of the Site identify a downward hydraulic gradient that may be representative of groundwater recharge components of the groundwater regime. Conversely, the pore water measurements taken from the drive points advanced in sediments within Mission Bay immediately adjacent to the north side of the Site identify an upward hydraulic gradient that may be representative of groundwater discharge components of the regime, into Mission Bay.

5.16 Disposal of Investigation-Derived Waste

Soil cuttings, purged groundwater, and rinsate generated during the monitoring well installation activities were placed in appropriate 55-gallon drums and stored on-site pending disposal. Eleven drums of soil cuttings and one drum of rinsate were transported off-site on December 2, 2004, under manifest to D/K Environmental of Vernon, California for disposal. A copy of the manifest is provided in Appendix 5.21.

6.0 DISCUSSION OF RESULTS

Specific details regarding the results of the field investigation are summarized by field task in Section 5. For example, Section 5 includes descriptions of the field methods and laboratory analyses used to examine soil, landfill gas, sediment, and groundwater. The intent of this section is to provide an overview summary of the recent field investigation together with previously collected data and observations. Included are evaluations of the physical characteristics of the site and COPC summaries based on initial screening criteria. Additional review of the COPCs is conducted in the risk assessment sections (Sections 8 and 9) where all of the COPCs are evaluated in detail.

6.1 Landfill Characteristics (Physical)

The physical description of the landfill is important to evaluating existing conditions and for determining the integrity of the landfill containment system. Although this should not be considered to be a landfill that meets current landfill design specifications, the refuse is entirely covered and it is laterally contained.

6.1.1 Extent and Thickness

One of the goals of the site assessment was to determine the horizontal and vertical extent of the landfill. The horizontal extent of the landfill is depicted in Figure 6.1 and is based on review of aerial photography together with observations made during the advancement of soil borings and exploratory trenches within, and in the immediate vicinity of the landfill boundary. Also shown in the figure are the locations of borings, monitoring wells, and trenches used to delineate the landfill. Although there are borings located within the landfill boundary, which had no evidence of refuse, there are a number of reasons why this may have occurred so the landfill boundary is considered to be coincident with the zero foot waste thickness contour.

The landfill boundary was primarily identified from the historical data. Many of the borings were installed around the edge of the landfill in an attempt to refine the estimated boundary. If waste was found in a boring, the boundary was moved outside that boring location. However, if no waste was found in a boring the boundary was not moved inside the boring because there are at least three reasons why waste might not have been observed in a boring: a) the boring might have penetrated a zone of soil between the areas of waste, b) the boring might have penetrated some zone(s) of waste but collected no recognizable waste due to decomposition in the landfill, or c) the boring might have penetrated some zone(s) of waste but collected no recognizable waste due to the small diameter of the sampler.

Overall, there is a higher degree of certainty regarding the landfill extent than was previously provided for the western and northern edges. A portion of the perimeter remains indicated by dashed lines in Figure 6.1. In these areas the potential uncertainty ranges from approximately +/-10 to 30 feet. Also noted in Figure 6.1 is an area of refuse that was excavated during the construction of the South Shores Boat

Basin. In particular there is an area within the southeastern portion of the boat basin, coincident with the historical San Diego River Channel, which required the excavation and removal of soil, sediment, and refuse. A second “lobe” inferred from aerial photographs occurs in the northeast corner of the site.

Soils data have been compiled to estimate the thickness of the landfill in Figure 6.1. The following volumes and areas have been derived from analysis of the maps, primarily by using planimetric estimation of areas within thickness contours:

Landfill Area = 113 acres.

Landfill Volume = 487.6 acre-feet, or 786,598.6 cubic yards.

Average Landfill thickness = 11.3 feet, ranging from 0.5 to 22.5 feet.

Volume of Soils Capping the landfill = 118.7 acre-feet, or 191,580.4 cubic yards.

Average Landfill Soil Cap thickness = 9.3 feet, ranging from 1.5 to 19.5 feet.

It is important to note that the base of the landfill that was present during landfill operation may not coincide with the depth that refuse was observed in borings because compression of the refuse can cause materials to be driven into the underlying soil and sediment. In addition, degradation of the landfill refuse has occurred since the landfill closed which would result in a reduction of volume as well as landfill gas generation. The landfill is composed of both refuse and soils used during landfill operations to cover the refuse, typically on a daily to weekly basis. Thus the landfill thickness and volume represents a combination of soil and refuse, although the contours represent only the areas within which refuse was observed at the appropriate depths. In some areas within the landfill footprint, particularly at the margins, it is possible to encounter little to no refuse where borings penetrated soils that are situated between refuse cells (Figures 6.1 and 6.2).

6.1.2 Landfill Cover and Surficial Features

The landfill refuse materials are not exposed and are completely covered by soil. Portions of the landfill cover soils are in turn covered by roads, parking lots, landscaped areas, and hardscape (such as sidewalks). The thickness of the landfill cover is depicted in Figure 6.2 and is based on review of aerial photography together with observations made during the advancement of landfill gas sampling probes, previous excavations, and from the soil borings within, and in the immediate vicinity of, the landfill boundary. In general the landfill increases in thickness towards the center of the Site and thins towards the perimeter.

The following volumes and areas have been derived from analysis of the maps:

Landfill Area = 113 acres.

Volume of Soils Capping the landfill = 118.7 acre-feet, or 191,580.4 cubic yards.

Average Landfill Soil Cap thickness = 9.3 feet, ranging from 1.5 to 19.5 feet.

Area of Landfill covered by asphalt and concrete = 34.6 acres (30.6% of total).

Area of landfill where active irrigation occurs = 6.0 acres (5.3% of total).

Further description of the landfill cover and surficial features follows.

6.1.2.1 *Topography and Drainage*

The Site is located at an approximate elevation of 20 to 25 feet above mean sea level (MSL). Figure 6.3 depicts the current topography of the Site together with a summary of the type of surfaces that occur within and adjacent to the landfill. The surface water drainage system for asphalt and concrete surfaces leads water away from the higher areas of the Site as illustrated by the arrows shown in the figure. Also noted in the figure are storm drains that empty into either the San Diego River or Mission Bay.

Depicted in Figure 6.3 are arrows that show drainage patterns in areas of the landfill boundary. In general, drainage at the Site is governed by surface material composition (dirt or paved) and topography. Most notable of the paved areas within the Site is the northward drainage of the South Shores Parking Lot to the boat basin. The northern half of the Site drains to the bay and the southern half of the Site drains to the San Diego River floodplain. Drainage on the southern side of the Site is also facilitated by three stormwater outfalls shown in Figure 6.3. Rainfall infiltration occurs in all unpaved areas of the Site with additional infiltration occurring in irrigated areas that contain landscaping. In arid areas like San Diego County where rainfall amounts are minimal, irrigation can provide the majority of infiltrating waters adding to the groundwater regime.

Drawings of the Site and surrounding area showing the distribution of underground utilities were obtained from the City of San Diego. With the exception of the area along Sea World Drive and the restrooms near the boat basin, there are few utilities within the South Shores area. One sanitary sewer line runs west from the restrooms by the boat basin and then south to join the main sewer line along Sea World Drive. There are storm sewers for surface drainage in the paved areas of the park, but no map was reviewed. The other utility at the site is electricity for the lighting in the paved areas. No information was reviewed concerning the depth of the utility trenches or the possibility that buried waste was disturbed during their excavation.

6.1.2.2 *Soil Cover Thickness*

The thickness of the landfill soil cover varies significantly and ranges from 1.5 to 19.5 feet, and averages 9.3 feet. In general, the cover soils decrease in thickness towards the center of the landfill and are less than 5 feet thick in two areas located in the eastern and western portions of the landfill. The approximately 35-acre parcel located east of Sea World Drive and north of Friars Road has been observed to contain the least amount of landfill soil cap thickness (Figure 6.2), in places significantly less than 5 feet as indicated by the data depicted in the figure.

The function of the soil cover, and hence the significance of the cover soil thickness is to: a) disperse the venting landfill gas so that it is not present above the surface in a potentially toxic or explosive concentration; b) allow creation of an aerobic zone in

which degradation (oxidation) of methane and VOCs can take place; and c) to isolate the refuse from the public. Gas containment is addressed in Section 8.4.4. In short, although the soils are in some areas less than 5 feet thick, the cover soils do appear to largely limit the concentration of landfill gases reaching the ground surface.

6.1.2.3 *Landscaped, Irrigated, and Protected Areas*

The City of San Diego's South Shores Park, Sea World (owned by Anheuser-Busch and operating on land leased from the City), and public street easements overlie portions of the landfill. Review of the air photo-based maps (e.g., Figure 6.3) shows that the eastern portion of the Sea World Parking lot overlies the western portion of the landfill. The asphalt-paved parking lot is lighted and has perimeter landscaping. To the east of the Sea World Parking lot is the asphalt-paved parking lot for the South Shores Boat Ramp and Park. This area also contains lighting and landscaping. The eastern half of the landfill is undeveloped with the notable exception of Friars Road and Sea World Drive. To the south of Sea World Drive is an un-named frontage road.

Immediately south of the South Shores boat basin is an irrigated area of approximately 4 acres. Since hydraulic fill was used to construct much of the cover soil, extensive irrigation is likely necessary to wash out residual salinity and provide for plant growth. Electromagnetic (EM) geophysical survey profiles completed during the geophysical survey identified the irrigated area by higher resistivities (see Appendix 5.5A, Figure 11, Line 2). The electrical resistivity contrast is due to the flushing of saline vadose zone sediments by fresh water from irrigation.

The San Diego River Channel is an important wetland habitat. A portion of the Site, a triangular area located south of the intersection of Sea World Drive and Friars Road, contains a foredunes restoration area. Also, most of the area south of Sea World Drive has been designated as a California Least Tern colony.

6.1.3 *South Shores Boat Basin*

The South Shores Boat Basin was created by excavation of fill soils and sediments. Excavation began in 1988. It is located immediately north of the central portion of the landfill and construction necessitated the excavation of an unknown quantity of landfill refuse, hydraulic fill sands, and existing sediment.

The southern and southeastern portions of the slope between the landfill and the boat basin are coincident with the boundary of the landfill. A geotechnical component of the design includes the construction of a geotextile liner adjacent to the South Shores boat basin capped with sand and large angular boulders known as rip rap for slope stability.

6.2 Groundwater Conditions

Groundwater levels beneath the Site are just above mean sea level, and hydraulic influences include the tidally influenced Mission Bay to the north and the San Diego River Channel to the south. The flow of groundwater is hydraulically controlled by conditions within the San Diego River (to the south), and Mission Bay (to the north). Both are subject to tidal influences. Groundwater generally flows to the north across the Site, from the River to Mission Bay; however, reversals of the overall flow pattern occur along the Site margins during tidal events.

Most of the Site was constructed on wetlands. Prior to and during landfill operations the Site and the surrounding area were altered significantly, primarily due to the construction of Mission Bay Aquatic Park. A berm of coarse sand estimated to be over 300 feet wide was created before landfill operation that now lies between the landfill and the bay. A portion of this sand berm was excavated to form the South Shores Boat Basin.

The primary hydraulic influences on groundwater are the boundary conditions imposed by Mission Bay and the San Diego River. Review of the surface water drainage patterns, extent of impervious surfaces, and irrigation practices indicates that there will be rainfall recharge occurring at the Site. Leakage may also occur from buried water lines, sewer lines, and stormwater lines. However, an investigation of the subsurface utilities was not conducted, nor were there any apparent large-scale water chemistry changes that could be directly attributed to leaking utilities.

Groundwater monitoring wells and temporary drive points were the primary source of groundwater data. Groundwater chemistry data were also collected to assess the groundwater system.

SCS conducted monitoring of groundwater levels for a period of one month. Water levels were recorded at 10-minute intervals to observe the tidal influence on the wells. During the time of the SCS tidal study two large rain events (October 20 and 27, 2004) occurred that allowed for an opportunity to observe how flood events within the San Diego River affected the groundwater regime at the Site. An attempt was made to measure water levels in the San Diego River; however, the staff gauge was unexpectedly lost due to the power of the current or collision with entrained debris during the first flood event. Water levels in Mission Bay were obtained from tidal data specific to Mission Bay (Section 5.12).

6.2.1 Significant Physical Features

Many of the physical characteristics of the Site are significant from a groundwater perspective. The features of note include the following:

6.2.1.1 Mission Bay Aquatic Park

The portion of the man-made Mission Bay adjacent to the northern boundary of the Site is subject to daily oceanic tides because the bay is fully open to the Pacific

Ocean. There is a tidal lag, or delay, caused by the time required for the tidal pulse to move through the bay. However there is no significant difference between oceanic tidal levels and those experienced at the Site, except for the tidal lag (time delay).

6.2.1.2 San Diego River Channel (Historical and Current)

The former San Diego River Channel, which historically (pre-landfill) transected the Site and discharged to the bay in the area where the existing South Shores Boat Basin is located, was filled in with landfill waste and fill soil. (The former river channel is shown in many of the figures.) The river was re-routed to the west and currently flows due west approximately 2 miles to the Pacific Ocean. Although the mouth of the river channel is often filled with sand due to wave action, the channel is also influenced by oceanic tides that cause water in the river to “back up” at high tides. Thus tidal influences cause water levels to rise and fall on a daily basis on both sides of the Site, with stronger influences occurring along Mission Bay.

6.2.1.3 South Shores Boat Basin Barrier System

The potential hydraulic effect of the boat basin is two-fold. The basin excavation reduced the distance across the landfill from the river to the bay from approximately 1600 to 1000 feet. Since the overall hydraulic gradient is established by the difference in water levels between the river and the bay, the effect of the excavation was to significantly increase the hydraulic gradient across this area proportional to the decrease in distance (i.e., by a factor of 1.6). The decreased distance also acts as a “short-cut” for flow across the Site.

An offsetting condition for flow across the landfill at the boat basin is the presence of the barrier system (as discussed in Section 6.1.3). The slope and a portion of the basin were constructed with a high density polyethylene (HDTPE) liner that restricts groundwater flow. Groundwater will flow beneath the HDTPE liner. Two water samples were obtained from the boat basin using drive points. At both locations an upward hydraulic gradient was observed at low tide, indicative of the hydraulic pressure beneath the HDPE liner.

6.2.1.4 Saturated Refuse

A comparison of groundwater with the estimated base of the landfill is depicted in Figure 6.4. Subsurface conditions within the landfill are expected to be highly heterogeneous given the variations in fill patterns and refuse that occur. The elevation of the base of the landfill was estimated from the topographic map and the reported thickness of soil cover and refuse because many of the soil borings were not surveyed. Additional uncertainty occurs because, under compaction, solid refuse can be driven into the underlying soft sediments. The boring logs simply report the presence or absence of refuse.

The map shows that the refuse that resides in the landfill at an elevation of 3 feet above mean sea level and deeper is saturated by groundwater. A majority of the refuse in the landfill is interpreted to reside at or deeper than 3 feet above mean sea level. A comparison of the landfill phases shown in Figure 2.1 with the interpreted landfill waste base map (Figure 6.4) reveals a strong correlation of observed landfill refuse lateral extent with the landfill extents interpreted from our review of historical photos. It is also apparent that the deepest areas of the landfill are beneath the southwestern corner of the 35-acre parcel (late 1958) and in the northwestern corner of the landfill boundary beneath the western edge of the Sea World parking lot (March 1958).

6.2.2 Water Level Variations Due to Tidal Influences

Groundwater level fluctuations occur within the landfill on a daily basis. As described in Section 5.12, the water level data recorded in the wells was processed by taking an average of all the water levels recorded in a 24 hour 50 minute period (the duration of the lunar orbit). Successive averages calculated for consecutive sets of data are known as a moving average, which will reveal long-term trends in the data independent of the lunar diurnal variations.

A map showing the average water levels, indicative of the time-averaged hydraulic conditions, is presented in Figure 5.8. This map depicts water levels that occurred on October 16, 2004 at 12:00 pm prior to increased flows and ultimately flood flows in the San Diego River. The figure depicts the overall groundwater flow conditions that are expected to occur at the landfill.

Prior to the two large rainfall events, the groundwater elevation study provided data that allowed for the quantification of the tidal responses of groundwater elevations in wells at the Site. Please refer to Appendix 5.16 for the technical discussion of the theory and methodology of the pre-flood and post-flood groundwater tidal analysis. Figure 6.5 depicts observed groundwater elevations beneath the Site during a high tide prediction (October 14, 2004 at 9:43 am) and Figure 6.6 depicts observed groundwater elevations beneath the Site during a low tide prediction (October 14, 2004 at 4:13 pm). In these figures the 24:50 moving average was not calculated. Instead the instantaneous water levels obtained from the pressure transducers have been used.

Comparison of the (lunar) daily average and instantaneous water levels show that the water level elevations and observed hydraulic gradients are generally similar. The overall horizontal gradient under tidal conditions can be separated into three areas of the Site that demonstrate characteristic flow pathways. Those three areas are the western side of the Site beneath the eastern side of the Sea World Parking Lot and the South Shores Parking Lot, the central area of the Site in the immediate vicinity of the former San Diego River channel, and the eastern area of the Site in the vicinity of the intersection of Sea World Drive and Friars Road. The measured hydraulic gradients for the western area of the Site range from 0.002 to 0.004 foot/foot (ft/ft). The

measured hydraulic gradients for the central area of the Site range from 0.002 to 0.004 ft/ft. Lastly, the measured hydraulic gradient for the eastern area of the Site was consistent at a value of 0.0005 ft/ft.

The extent of saturated refuse appears to have some influence on the gradients. The eastern portion of the landfill has areas where saturated refuse extends from approximately 8 to 9 feet into groundwater (Figure 6.4). The horizontal hydraulic gradient is lower in this part of the landfill than further west, and the lower hydraulic gradient reflects the higher hydraulic conductivity (or intrinsic permeability) of the medium through which the groundwater is flowing. It is likely that compacted refuse will have a higher hydraulic conductivity than the fills soils dredged from the bay, so the greater thickness of saturated refuse in the eastern part of the landfill affects the observed gradients.

Vertical gradients along the northern and southern boundaries under low tide conditions were also measured on November 23 and December 9, 2004 by placing drive points into the sediments. Drive points are essentially simple shallow wells. Comparisons of the surface water and groundwater water levels were made at each point (i.e. by measuring the water level in the drive points and that outside of the drive point). If the surrounding water level is higher than that in the drive point this indicates that water will flow downward. Conversely, if the water level is observed to be higher within the drive point it means that water is flowing upward. The results of the drive point water level measurements under low tide conditions (Figure 6.7) show that the water appears to be flowing downward along the San Diego River Channel and upward within Mission Bay. In other words, the overall groundwater flow, even under low tide, appears to be from the river to the bay.

6.2.3 October 2004 Flood Events

The San Diego region experienced record rainfall in October 2004 (NOAA, 2005). These unexpected rainfall events led to flooding in the San Diego River. This was a fortuitous event since water levels at the landfill site were being continuously monitored in October and early November. Figure 5.9 depicts the groundwater elevation change associated with the first flood, and shows that groundwater levels rose up to 0.6 feet.

There were four primary effects of the flood event:

1. Groundwater levels rose and an additional portion of the landfill became temporarily saturated.
2. Fresh water recharge from rainfall occurred within the landfill footprint since only a portion of the landfill surface is paved.
3. Fresh water, rather than the saline to brackish water that normally occurs within the river channel, entered the groundwater system from the river.
4. The hydraulic gradient across the Site increased.

In this or other flood events, once flood waters recede it may also be possible that groundwater drainage will occur from the southern portion of the Site towards the San Diego River channel.

During the non-flood condition, the vertical hydraulic gradient observed during low tides was downward from the river and thus towards the bay (Section 5.15.2). The potential reversal is only postulated; no drive point water level measurements were obtained following the floods.

Finally note that all of the water quality parameter measurements were conducted during the tidal influence study. It is not known whether a sufficient volume of fresh water entered the subsurface during the flood to create a fresh water lens or layer of fresh water. The following section discusses the pre-flood water chemistry profiling results.

6.2.4 Water Chemistry Profiling

Total dissolved solids (TDS) is one of a number of water chemistry parameters that can be used to evaluate groundwater conditions that occur at the Site. Groundwater at the Site is predominantly saline to hypersaline, although some lower-salinity areas are brackish. Site TDS values ranged from 12,800 mg/l (Boring B7) to 64,000 mg/l (Boring B13). For comparison, the TDS content of local sea water is approximately 35,000 mg/l.

Groundwater chemistry data were collected from monitoring wells, drive points, and temporary borings. Selected data are depicted in Figure 6.7. Included are:

- TDS, a measure of salinity
- Nitrate
- Sulfate

Other data depicted in Figure 6.7 include:

- Tidal lag
- Tidal efficiency

Interpreted groundwater gradient directions have been portrayed in the three figures depicting groundwater elevation contours.

The TDS contours depicted in Figure 6.7 were produced from the reported TDS values of groundwater samples collected from the wells. This interpretation is two-dimensional and does not explicitly account for stratified conditions because the groundwater samples could represent a mixture of formational water from various depths or a more discrete sample representative of a specific depth. Vertical water quality parameter profiles were also performed within 11 of the wells at the Site to assess stratification and the potential for isolation of contaminants by a halocline, the potential for pH-controlled mobility of metals. The data collected from the stratification study were reviewed for general trends in water chemistry and to

provide an understanding of whether or not potential contaminants in the groundwater are isolated from surface waters by physical or chemical characteristics (e.g., flow stratification or pH-controlled solubility).

In general pH, conductivity, and TDS values increased with depth while temperature and dissolved oxygen decreased with depth. It was observed that 2- to 8-foot-thick layer of buoyant, brackish groundwater is entering the Site from the San Diego River. The thickest portion of this brackish layer of groundwater was observed in well SCS3 most likely due to the presence of the former San Diego River Channel. Salinities vary throughout the Site both laterally and vertically as a function of bay interactions. For example, the salinity profiles collected from the wells closest to the bay display TDS values for shallow groundwater above the observed halocline representative of the saline waters of the Bay while wells farthest from the bay display TDS values for shallow groundwater above the halocline to be representative of water from a brackish river system. It is also noted that the area of the Site with the highest hydraulic gradient (south of the boat basin) is also facilitating the farthest infringement of brackish groundwater into the Site from the river.

The conclusion that a halocline is present in the groundwater regime of the Site was based on the observation of salinity values (represented as TDS) fluctuating with depth. A majority of the graphs provided in Appendix 5.15 demonstrate the presence of a halocline with a marked salinity increase at the interface of buoyant brackish groundwater above denser hypersaline groundwater.

The majority of the low flow pumps appear to be set below or in the lower part of the transitional zone. The pumps tend to draw water from a range of depths even at low flow rates, so it is likely that mixing will occur during sampling and the samples collected during this assessment are not representative of only one zone of groundwater. However, the adjustment of pump intake depths to coincide with the less saline groundwater above the halocline should provide groundwater chemistry data more representative of impacts from dissolved phase COPCs. It should be noted that this does not apply to the metals data, because these samples were collected with single-use bailers from the shallow part of the water column in each well (as discussed in section 5.13).

Further review of salinity profiles collected from wells within or in the immediate vicinity of irrigation suggests there is no evidence of irrigation at the Site causing significant dilution of groundwater salinities by infiltration of fresh surface water.

6.3 COPCs in Surface Soil and Sediment

Surface soils containing COPCs such as metals and PAHs can be mobilized at the Site by natural processes such as wind and rain. If precipitation rates exceed the adsorption capacity of the surface soils it can produce soil erosion during drainage of the excess surface water that did not infiltrate into the vadose zone of the subsurface. This drainage water and incidentally entrained soil particles, with or without associated COPCs, has the ability to

leave the Site through the stormwater collection and displacement system and/or drainages such as the slopes at the Site boundary that are stabilized with rip rap.

The only COPCs that were reported above laboratory detection limits and were observed to be present in both sediment and surface soils at the Site are metals. Comparisons of known surface drainage patterns as well as the location of stormwater outfalls present at the southern edge of the Site (Figure 5.7) with reported metals concentrations in sediment and surface soil samples do not suggest a strong correlation. Most notable of the sediment and surface soil sample analytical results is that there appear to be higher lead concentrations present in the sediments comprising the San Diego River floodplain as opposed to those in Mission Bay and the surface soils throughout the Site. This could possibly be the result of accumulation from stormwater outfall locations or possibly from other point or nonpoint source(s) upstream to the east. Overall, the surface soils of the Site contain no COPCs at concentrations greater than the California Human Health Screening Levels. As a result there are no potential offsite impacts of concern.

6.4 COPCs in Landfill Gas

Gases occur within the landfill that primarily form as a result of the biodegradation of organic compounds. A second gas source produced by the direct volatilization of volatile organic chemicals (such as the solvents trichloroethene [TCE] and tetrachloroethene [PCE]), was also observed to occur but at significantly lower concentrations. Both subsurface and above-ground testing was conducted to assess the types and concentrations of gaseous COPCs that occur at the landfill. The test results for VOCs can also be used to determine if residual sources of VOCs occur within the landfill.

6.4.1 Subsurface

Methane is a gas that occurs from the biodegradation of organic material in the relative absence of oxygen; it occurs in most landfills. Testing was conducted to assess biogenic gas concentrations as described in Section 5.5. Figure 6.2 depicts the percentage of methane and hydrogen sulfide detected prior to the collection of the landfill gas samples. Methane is detectable throughout the landfill at concentrations ranging from below the detection limit to 57 percent by volume. Comparison of Figures 6.2 and 6.4 shows that the area of methane concentration greater than 15% coincides with the area where the base of the landfill waste is below groundwater.

LFG generation typically decreases over time with continued degradation of the organic materials in the landfills. Another analysis of the LFG data provided an assessment of the relative methane production rates expected to occur at the landfill. The results, presented in Section 5, indicate that the highest LFG generation rate occurred in 1960 with a rate of 996 cubic feet per minute (cfm). The results of the LFG generation model can be found in Table 5.10. A more detailed explanation of the LFG generation modeling (based on the EPA's LANDGEM model) is included in Appendix 8.6 and in the human health risk assessment (Section 8).

Based on commonly utilized generation models, landfill gas generation declines asymptotically over the years, i.e., it theoretically never reaches “zero”. The EPA-sanctioned model used in this report is consistent with this. It shows that the MBLF is currently generating methane at about 10% of the rate it generated upon closure. It is true that many regulations call for 30-years of post-closure care at landfills, but this is based on the assumption that the small amount of gas still being generated after 30 years will somehow not be significant. However, all landfills (that we are familiar with) that ceased operations 30+ years ago are still, in fact, generating methane. Regulators are becoming cognizant of this, and it is likely that they will require most landfills to continue maintenance and monitoring functions after the initial 30-year post-closure period concludes.

Hydrogen sulfide is another biogenic gas that was observed within the landfill. It also occurs naturally in chemically reducing environments. Hydrogen sulfide gas produces an offensive “rotten egg” or “sulfur water” odor often characteristic of anoxic sediments. It has a relatively high toxicity and can be a significant health concern. The concentration values are plotted in Figure 6.8 but were not contoured because the distribution is irregular. The highest observed concentrations occur fairly equally spaced throughout the Site and do not necessarily correspond with the extent of saturated landfill refuse shown in Figure 6.5. However it may be worth noting that the highest observed concentration of hydrogen sulfide (21 ppm) was collected from one of the deepest areas of the landfill refuse.

Of significant concern is the potential for organic solvent vapors to occur, based upon historical records indicating the disposal of organic solvents such as TCE that are currently classified as hazardous waste. Landfill gases were tested for organic compounds. The results of this analysis suggest that organic compounds including biogenic gases, chlorinated solvents and their chemical breakdown products, and aromatic hydrocarbons and their chemical breakdown compounds are present in landfill gas beneath the Site (Sections 5.5.1.4 and 5.5.2.1). However no spatial patterns were observed for detections of COPCs in landfill gas. A discussion of the human health risks associated with COPCs detected in landfill gas can be found in Section 8.3.4.

6.4.2 Surface Emissions

Since the presence of large percentages of methane in the subsurface is often expected, monitoring of methane at the land surface above the landfill and cover soil can a useful indicator of the potential for gases to escape into the atmosphere. The gases may also enter into the breathing zone of humans and animals at or adjacent to the landfill.

Composite surface emission and ambient air sample results (Section 5.5) showed that methane is virtually undetectable in surface air at the Site. A discussion of the human health risks associated with near-surface (in the cover soils) and surface emissions is presented in Section 8.3.

6.5 COPCs Within Landfill and Landfill Content

6.5.1 Within Landfill

Determining what is in a landfill, or more specifically what toxic or hazardous substances are in a landfill, through direct testing/sampling of refuse, is not commonly undertaken, nor even considered practical. Direct sampling of refuse poses tremendous problems, perhaps best characterized by the needle in the haystack analogy. Waste is heterogeneous (composed of thousands of materials and substances), as well as anisotropic (its characteristics vary randomly, not related to a direction or depth). Obtaining “representative samples” of waste from a landfill is nearly impossible, because no single material within the landfill is representative of everything else. Theoretically, if enough samples are taken (thousands perhaps), and reduced/pulverized/homogenized into a testable mass, some mathematically defensible overall landfill chemical composition could be determined, but it would not be of much use.

However, such direct testing of the refuse mass is not necessary, either. The main objective of any environmental investigation, whether for a landfill or other source, is not really to determine what the source is, but rather what its impact would be on the environment, on the humans or other life which may interact with the site. Characterizing the source, or more specifically its chemical composition, can be helpful, but is not always essential. And whereas determining what is within the site (what is in the refuse) is extremely difficult, determining what the landfill’s impacts are is more straightforward and manageable.

It is strongly suspected, from the historical record, that the Mission Bay landfill contains hazardous waste, most likely in the form of drums of spent materials (solvents?). However, all municipal waste landfills, even the best-operated modern sites, contain some quantities of hazardous materials. This includes typical household hazardous waste, e.g. not-completely-empty containers of solvents (thinners, cleaners, glues, fuels, etc.), components of household electronics, residual chemicals from dry-cleaning or other processing. But it may also include deliberately discarded (illegal) hazardous waste that escapes detection.

Modern hazardous waste screening procedures at landfills were not practiced before 1980, so older landfills, such as Mission Bay, commonly and often systematically received larger quantities of hazardous waste.

Further, it should be understood that the disposal of waste in a landfill is intentional (and, usually, well organized). It is not itself a spill, leak, or slow release (though it may leak). If the landfill is functioning successfully, it will contain all types of non-native substances (refuse, some of which may be hazardous), but they *will remain in the landfill*. That is, potentially hazardous contaminants will be *contained within the site*. Even old landfills, such as Mission Bay landfill, were intended to contain waste via the earthen sidewalls and the soil cover; this was the goal of “sanitary landfilling”

(as opposed to “open dumps”). More modern sites augment this containment with engineered liners and covers (often with synthetic materials), along with mechanical gas control and liquid removal systems. The “proof” that the containment strategy is working is obtained through monitoring systems – e.g. gas and groundwater monitoring wells, air emissions monitoring, and surface water monitoring. If these systems do not detect leakage, the landfill is considered successful, even though there may be dangerous materials within it. Long term monitoring is designed to give an early warning to a potentially dangerous release, allowing time for appropriate mitigation.

The ability to monitor any significant release of hazardous contaminants is the way by which all modern landfills are scrutinized. And the same types of monitoring activities have been undertaken at Mission Bay landfill, and are substantially expanded upon in this Site Assessment. Further, the greatly expanded environmental data set, which has been put together in the course of this project, has been analyzed through modern, regulatory-approved techniques of Human Health Risk Assessment and Ecological Risk Assessment. These monitoring and assessment techniques provide a more useful knowledge of the landfill’s environmental impact and risk, than a complete knowledge of the composition and geometric distribution of the actual landfill contents.

The completion of direct sampling of materials within the landfill also is difficult due to inherent restrictions that conventional soil sampling equipment has with heterogeneous media possessing the dynamic physical characteristics experienced with landfill refuse. For example, a large piece of wood or metal debris can be forced deeper into the subsurface by the auger and/or drive sampler during soil boring advancement and soil sampling activities, making the actual depth of that material difficult to properly quantify. Exploratory excavation can be used for purposes of assessment and was conducted at the Site in February of 1980. However this disturbs the protective soil cap and may produce a regulated waste that must be handled accordingly. Soil borings B14, B16, and B17 were completed within the landfill area during this assessment.

The presence of organic landfill components and the degree to which those components have been degraded by natural processes can be inferred from the presence of different biogenic gases in the subsurface. No discernable spatial patterns of detected landfill gases were observed, with the notable exception of methane. The completion of a geomagnetic survey was employed to attempt to locate metallic landfill components (Figure 5.1). No obvious indications of large-scale accumulations of metal within the landfill were observed in the results of the geophysical survey.

6.5.2 Adjacent to Landfill

A review of the analytical results of soil samples collected from the subsurface of the Site suggests that the semivolatile compound bis(2-ethylhexyl)phthalate, PAHs, and metals are the primary concern. Soil samples collected adjacent to the landfill were

not observed to contain notable concentrations of these COPCs. No spatial patterns were observed for reported detections of COPCs in soil adjacent to the landfill (Figures 5.4 and 5.5).

6.6 COPCs in Groundwater

The transport of detected COPCs such as volatiles, semivolatiles, and metals within the deeper part of the landfill is controlled mostly by the movement of groundwater containing dissolved phases of these contaminants. Although it appears that groundwater samples collected from soil borings advanced around the periphery of the Site (B6-GW, B7-GW, B9-GW, B18-GW, B15-GW, B13-GW, and B12A-GW) were reported to contain fewer quantities of analyte detections as opposed to those advanced in the interior of the Site (B10A-GW, B14-GW, B16-GW, B17-GW), no other notable spatial patterns of detected dissolved-phase COPCs were observed.

Nitrate was not detected in groundwater. Sulfate concentrations appear to be elevated (>2,000 mg/L) at monitoring wells located at the periphery of the Site as opposed to those located in the interior of the Site (Figure 6.7). This spatial phenomenon could possibly be caused from anaerobic degradation of nitrate and sulfate within the landfill refuse during biotransformation processes. The lack or lower occurrence of these biotransformation processes in portions of the Site adjacent to the landfill refuse would allow for more sulfate to be present.

The reported TDS concentrations of groundwater and pore water samples collected from the soil borings, monitoring wells, and drive points at the Site were contoured in Figure 6.7. Some of the highest TDS values were observed in the portion of the Site south of the boat basin (MBE4 and B16), as well as at B13. The lowest concentrations of TDS were observed in the southwest and southeastern corners of the Site where freshwater additions to the groundwater regime are reducing salinity values such as TDS.

6.7 COPC Mobility and Fate as Controlled by Landfill Characteristics

The movement and fate (chemical transformation) of chemicals within the landfill is related to the physical, chemical, and microbiological characteristics of the subsurface. All of these factors are inter-related and can be described in extensive detail. This section will focus on an overview description of VOCs and metals as examples since the primary COPCs fall into these categories. References are provided should the reader desire additional technical details regarding COPC mobility and fate.

Chemicals within the landfill can simultaneously occur in a number of phases, depending upon their physiochemical characteristics. These phases include:

- Dissolved in water
- Temporarily or permanently bound to solids (such as soil) at a molecular level
- Vapor phase
- Pure solid or liquid phase.

For example, consider a volatile organic chemical (VOC) such as the chlorinated solvent trichloroethene (TCE). Spent solvent TCE placed in the landfill environment will distribute itself among a number of phases: pure liquid phase solvent, dissolved in water, sorbed to soil, and as TCE vapor. Thus it can be detected in different types of samples (water, soil, and vapor) depending on what happened after it was distributed in the subsurface within the landfill. Metals, such as arsenic, are typically not volatile and will not occur, as or be transported as vapor. However they will occur in minerals (solid phase), dissolved in water, and attached to soil particles. Both metals and organic compounds can undergo chemical transformation in the subsurface where they can degrade or become combined with other organic or inorganic chemicals.

The fate and mobility of chemicals in the subsurface is highly dependent on the chemical environment. A dominant characteristic of subsurface conditions within the landfill is the existence of chemically anoxic, reducing conditions. These conditions are demonstrated by the presence of significant concentrations of methane (CH_4) and hydrogen sulfide (H_2S) gases and an absence of oxygen. Microbial degradation of organic materials, such as landscaping wastes placed in the landfill, initially occurs under aerobic conditions when oxygen is available. Once oxygen is consumed the microbial assemblage evolves and adapts to anaerobic conditions. Sequentially the degradation processes (in terms of the source of energy for microbes) move from aerobic respiration (oxygen), to denitrification (nitrogen, NO_3^- to NO_2^-), to iron reduction (iron, Fe^{+3} to Fe^{+2}), to sulfate reduction (sulfate, SO_4 , consumed to produce sulfide, HS^-), and ultimately to methanogenesis (carbon dioxide is consumed and methane is produced). (for more details refer to Dragun, 1988). Sulfate reduction and methanogenesis are the dominant chemical processes that occur within and adjacent to the landfill.

Chemical transformation of COPCs, typically related to biologically-mediated degradation, is expected to occur within the landfill. Landfills are biologically active. Water is necessary for microbial life, and the site characterization has shown that the base of refuse of the Mission Bay Landfill is below groundwater. Rainfall and irrigation waters are also capable of entering the refuse over much of the landfill area.

Microbial activity within the landfill will degrade many organic compounds, including COPCs. For chlorinated VOCs the chemical conditions at the landfill support a process known as reductive dechlorination (USEPA, 1996). TCE, for example, is sequentially degraded to DCE, then to VC, then to ethene and ethane. The degradation products, especially vinyl chloride, can be more toxic and mobile than the parent compounds.

Metals, on the other hand, do not degrade. However, the chemical environment can cause the mobility and toxicity of the chemicals to change. The pH of the landfill can also be important as metals are typically more mobile in acidic environments. Review of water chemistry testing at the site shows that pH conditions are relatively consistent, likely due to the buffering effect of the relatively high TDS waters. Hence the primary control on metals mobility is the electrochemical potential (measured as Eh), a measure of the degree of chemical oxidation and reduction occurring in the landfill.

6.7.1 Groundwater Transport

Chemicals dissolved in groundwater will be transported as groundwater flows in the subsurface. The groundwater flow pattern, that is the direction and magnitude of flow, will generally predict how dissolved chemicals will be transported. Of concern at this Site is the movement of groundwater from the landfill into the adjacent Mission Bay and San Diego River. Groundwater flow is complicated by the action of the oceanic tide. Tidal action increases dispersion due to the two-way action of the tide increasing net residence time and varying the rate of groundwater flow.

The overall horizontal gradient under tidal conditions can be separated into three areas of the Site that demonstrate characteristic flow pathways. Those three areas are the western side of the Site beneath the eastern side of the Sea World Parking Lot and the South Shores Parking Lot, the central area of the Site in the immediate vicinity of the former San Diego River Channel, and the eastern area of the Site in the vicinity of the intersection of Sea World Drive and Friars Road. Maps show inferred gradient to be in an overall northerly direction from the San Diego River through the Site to Mission Bay at approximately 0.002 to 0.004 ft/ft.

Tidal action creates a time-varying change in groundwater flow, particularly at the periphery of the landfill where groundwater discharges from the landfill into Mission Bay. Oscillatory tidal action and mixing with the bay waters cause the discharged concentrations of chemicals dissolved in groundwater to decrease relative to those that occur within the landfill. In general it is anticipated that tidal effects will lead to relative dilution rates on the order of 10:1 where the discharge concentrations decrease by a factor of 10 as compared to those occurring within the landfill. Examples of a numerical analysis of the effect of tidal conditions on groundwater conditions include Yim and Mohsen, 1993 and Carr, 1971.

The long-term average hydraulic gradients at the Site have been estimated from the tidal data recorded at the Site. If the October tidal conditions are judged to be representative of hydraulic conditions, the data can be used to estimate the approximate volume of groundwater flow from the Site to Mission Bay. A range of values are given here since there has been no direct testing of the relative permeability (hydraulic conductivity) of the subsurface. The steady-state flow across the northern boundary is calculated using the Darcy Equation where:

$$Q = K \text{ del}H A$$

Q, is the flow rate, ft³/day

K, is the hydraulic conductivity, a range of 2.83 to 0.283 ft/day

DelH, is the average hydraulic gradient across the discharge area, (ft/ft)

A, is the cross-sectional area for flow, 4400 x 15 ft, or 66,000 ft².

A cross-sectional depth of 15 feet is used to calculate the flow. This corresponds to the approximate saturated thickness of sands and silts that were placed to the north of the landfill. The average horizontal gradient ranges from 0.002 to 0.004 ft/ft.

The hydraulic fill placed along the 300-ft-wide northern boundary sand berm is known to have been selectively chosen from a range of potential fill materials. Thus the hydraulic conductivity of site soils is estimated to range between 10^{-3} and 10^{-4} cm/sec (2.83 to 0.283 ft/day), corresponding to either a fine-grained sand or a silty sand.

A range of potential flow rates is calculated using the upper and lower estimates of the hydraulic conductivity and of the hydraulic gradient. These are shown in Table 6.2 below:

Table 6.2 Calculated Groundwater Discharge Rates

Q, ft³/day	K, ft/day	delh	width, ft.	depth, ft.
374	2.83	0.002	4400	15
747	2.83	0.004	4400	15
37	0.283	0.002	4400	15
75	0.283	0.004	4400	15

The values presented in Table 6.2 represent averaged conditions across the northern boundary. Review of the range in gradients (Figures 6.5 and 6.6) shows that the highest gradients occur at the boundary of the boat basin. However, there is an impermeable sheet that was placed along the boundary at the time of the boat basin construction that extends into Mission Bay. The barrier increases the relative groundwater flow path for waters that flow past the barrier and discharge to the north of the boat basin.

Groundwater that enters the bay becomes mixed with a relatively large body of water that undergoes daily tidal action. The volume of water flowing from the landfill towards Mission Bay along the northern landfill boundary is estimated to be approximately 37 to 747 cubic feet per day. In comparison, if the area of Mission Bay to the north of the landfill is approximated to be 4,400 x 700 feet, a 3-ft to 6-ft tidal water level variation will lead to a daily exchange of 9.24 to 18.48 million cubic feet in Mission Bay.

Estimates of tidal attenuation (dilution) within the sediment were not calculated for the site, although the relative attenuation rate is expected to be on the order of 10:1. Instead a direct comparison of groundwater samples obtained from within and adjacent to the landfill was conducted by obtaining drive point samples. The results of the drive point samples obtained from the boat basin (Figure 5.6) did not reveal the presence of any organic COPCs. Low concentrations of metals were detected.

From a larger perspective, Mission Bay is federally-listed as an impaired water body due to coliform bacteria, an organism typically related to human and animal feces. Ongoing separate coliform investigations are being conducted.

6.7.2 Vapor Phase Transport

Volatile organic chemical vapors and other gases such as methane and hydrogen sulfide occur in the subsurface of the landfill. The movement of vapors from the subsurface will occur either as a result of pressure (advection) or concentration gradients (diffusion).

A significant portion of the field testing was dedicated to the testing of vapors (gases) within and immediately above the landfill surface. The results are presented and analyzed in the Human Health Risk Assessment (HRA) (Section 8). Included in the HRA analysis is an examination of the long-term potential for methane generation using landfill gas (LFG) generation calculations, and calculations of the potential accumulation of volatile organic vapors into a hypothetical building constructed on the landfill using a heuristic vapor transport calculation methodology (the Johnson-Ettinger model). Refer to Section 8 for additional discussion.

6.7.3 Geochemical Transformations

As previously discussed, the primary subsurface environment within the landfill is chemically reducing. Gases detected within the overlying soil cap remained relatively low in oxygen; however, concentrations closer to that of atmospheric oxygen are expected to be encountered in shallow near-surface soils. Saline groundwater occurs within the base of the refuse, and fresher surface waters likely infiltrate the unpaved portions of the soil cap during seasonal rainfall events or where irrigated landscape exists.

6.7.3.1 HVOCs

Reductive dechlorination will occur given the chemical environment that occurs at the Site (Pankow and Cherry, 1996). The following degradation sequence occurs:

Tetrachloroethene (PCE) => TCE => Dichloroethene => Vinyl Chloride (VC)

An examination of the analytical results in terms of the relative abundance of HVOCs follows in Table 6.1. Comparison of the relative ratios of HVOC concentrations shows that in all cases where TCE is detected the concentrations of VC are greater. Further, no detectable PCE concentrations were reported. Review of the groundwater data (Sections 5.13 and 6.6) shows that HVOCs have rarely been detected and, where detected, the concentrations have been low and similar in magnitude to allowable drinking water concentrations (e.g., 5 µg/L for TCE).

Overall the analytical data show that either significant degradation of HVOCs has occurred, or significant quantities of PCE and TCE were not put in the landfill. Historical documentation indicates that significant quantities of wastes were placed in the landfill approximately 50 years ago, however the majority of these wastes do not appear to have been solvents. Given the relative ratios of degradation products, the highly reducing geochemical environment, and the duration of time, it is likely that the solvents that were present have undergone an extensive and advanced process of degradation.

Attenuation of COPCs in landfill gas occurs within the soils that overlie the Site. The ratio of vinyl chloride concentrations in the landfill gas (LFG) and shallow soil vapor (SUR) is calculated in Table 6.1. Eight of the ten locations had detectable vinyl chloride in the LFG, and at four of those locations there were no detectable concentrations of vinyl chloride in the near-surface soil vapor. In all cases the concentration of vinyl chloride decreases, and the average ratio is 0.22. The decrease is likely due to both dilution and aerobic degradation of vinyl chloride.

There is a lack of evidence of liquid phase HVOCs. A typical rule of thumb is that dissolved PCE and TCE concentrations would be expected to occur at concentrations of approximately 1 to 10% of the aqueous solubility (Pankow and Cherry, 1996). Their reported solubilities range from 150,000 to 200,000 µg/l and from 1,100,000 to 1,366,000 µg/l, respectively. A solubility of 1% would result in reported concentrations well in excess of 1,000 µg/L. Review of the groundwater sampling data (Sections 5.13 and 6.6) shows that reported dissolved concentrations are well below levels that would suggest the presence of free phase solvents.

Historical waste disposal practices included placing waste solvents in metal drums. While the drums would be expected to corrode in the saline subsurface environment, there is a potential for future releases to occur from sealed drums should they remain intact after 50 years. Continued groundwater monitoring of the Site is anticipated and should be capable of detecting a release of pure phase solvents should a release occur, especially given the large increase in concentrations that would occur if the concentrations meet or exceed 1 to 10% of the aqueous solubility limits noted above.

6.7.3.2 *Metals*

Both organic and inorganic forms of metals occur. Under strongly reducing conditions, such as those that occur at the Site, many metals will undergo chemical reduction and change valence state. In general, the reduced forms of the metals are less mobile. Of primary concern is the potential for metals to be transported as a dissolved phase in groundwater.

Summary reviews of the environmental fate of metals and other substances are available from the Agency for Toxic Substances and Disease Registry (ATSDR), an agency of the US Department of Health and Human Services. The reader is referred

to <http://www.atsdr.cdc.gov/toxprofiles> for additional information for metals such as arsenic, chromium, mercury, thallium, and vanadium.

Since the landfill is capped with soil and refuse is not exposed, the primary transport route for metals will be in a dissolved state. The fine-grained sands and silts that define the lateral limits of the landfill will essentially filter solid materials should suspended particles occur in water within the landfill. Review of the groundwater data, particularly the ultra-low detection analyses conducted for metals, shows that the dissolved concentrations of metals are relatively low.

Chromium is used here as an example of how the geochemical environment affects metals mobility. Chromate wastes, likely acidic, were reportedly disposed of at the landfill. Chromium typically occurs as either a hexavalent or a trivalent form (Cr^{+6} or Cr^{+3}). Hexavalent chromium is water soluble and toxic. When it is chemically transformed to trivalent chromium (by electrochemical reduction), it becomes less soluble and much less toxic (see the ATSDR reference or USEPA, 2000). Figure 6.9 depicts the form of chromium that will occur as a function of Eh and pH. Recent groundwater samples collected from soil borings and groundwater monitoring wells were reported to have pH values ranging from 6.63 to 7.37. The Eh condition that supports sulfate reduction and methanogenesis (as observed at the landfill) is less than -160 mV (Morrison et al, 1999). A box is indicated in Figure 6.9 that shows that only trivalent (Cr^{+3}) will be in chemical equilibrium under these conditions.

Field sampling analytical results for hexavalent chromium indicate that it was not detected in groundwater.

7.0 SITE CONCEPTUAL MODEL

The Site Conceptual Model (SCM) provides the reader with an overall understanding of the general landfill characteristics, the geologic and hydrogeologic nature of the Site, and the distribution of contaminants in soil, sediment, groundwater, and soil vapor. It is a summary of information regarding the landfill and has been created by compiling the data obtained and discussed in other sections of this report into one coherent model. Therefore, it includes some repetition of information that has been presented elsewhere in the report. The SCM is used to identify the potential pathways and receptors for potential contaminant release scenarios from the landfill, and forms the basis for the risk assessments (Sections 8 and 9). The importance of the SCM is that it establishes the basis for determining the risks to potential receptors and the framework for the investigation and remedial effort to be conducted at the Site.

Numerous changes have been made to the preliminary SCM that was presented in the workplan. Several new sections have been added, and the section on technical issues/data gaps has been removed (and placed in Section 4.0 Technical Background) because most of these have been addressed. The main issue that has not been addressed completely is the location and depth of utilities at the Site. In addition, the chemical and physical information obtained during the fieldwork part of this assessment has been included so several sections (e.g. Hydrogeology) have been expanded substantially.

There are figures from other sections of this report referenced in this section including:

Figure 1.1 depicts the Site location.

Figure 6.1 shows the thickness of waste within the landfill.

Figure 6.2 shows the thickness of the landfill soil cover.

Figure 6.3 shows the surficial site features and current Site topography.

Figure 6.4 shows the estimated elevation of the base of waste within the landfill and the extent of waste within groundwater.

Figure 6.8 shows the methane and hydrogen sulfide concentrations measured within the landfill.

Figure 7.1 depicts a schematic cross-section of the landfill.

Figure 8.1 is a chart that identifies the potential release mechanisms and receptor population relative to the landfill.

Please note that additional information and discussion in support of this SCM can be located throughout the text.

7.1 Site Setting

The 113-acre Mission Bay Landfill is located within Mission Bay Park, near the mouth of the San Diego River, and borders the south side of Mission Bay (Figure 1.1). It is within South Shores Park of Mission Bay Park, owned and operated by the City of San Diego. As such much of the Site is within a recreational use area and open to the public.

The aerial photograph base shown in most of the figures depicts the main features of the Site and the lateral limits of the landfill. The following features are evident in the photo:

- The areal limits of the 113-acre landfill.
- Sea World Drive and Friars Road intersect on the Site.
- The northern side of the San Diego River Channel. The bank is stabilized by boulder-sized rip-rap.
- The western edge of the Site covered by the far eastern edge of the parking lot for Sea World.
- The eastern side of the Site is bounded by Interstate Highway 5.
- Walkways and structures of South Shores Park.
- A boat basin and corresponding ramp and parking lot operated by the City of San Diego.
- The portions of the Site that are not covered by structure, pavement (including roads), and landscaping such as planted trees and shrubs and mulch, are unlandscaped sandy soils with varying amounts of vegetation. Approximately 30.6% of the landfill is covered by asphalt and hardscape. Another 5.3% is irrigated landscape.

7.1.1 Geography and Geology

As interpreted from a United States Geologic Survey (USGS) topographic map and monitoring well survey data, the Site is located at an elevation of approximately 20 feet above mean sea level. A topographic map has been included as presented in Figure 6.3. In general, drainage at the Site is governed by surface material composition (soil or paved) and topography. Most notable of paved areas within the Site is the northward drainage of the South Shores Parking Lot to the boat basin. The northern half of the Site drains to the bay and the southern half of the Site drains to the San Diego River floodplain. Drainage on the southern side of the Site is also facilitated by three stormwater outfalls shown in Figure 6.3. Rainfall infiltration occurs in all unpaved areas of the Site with additional infiltration occurring in irrigated areas that contain landscaping.

Mission Bay was formed in the topographic depression created by the subsidence of the southern flank of the Soledad Mountain anticline. A delta was built where the San Diego River flowed into Mission Bay. The deltaic sediments consist of alternating beds of sand and silty clay to a depth of approximately 100 feet below sea level (Marine Advisers, 1957). Other sources of sediment for Mission Bay have included Rose Creek, Tecolote Creek, and the ocean beaches.

The changing depositional environments present in the area of the Site led to the formation of a heterogeneous mass of deltaic sediments. Historically the San Diego River alternatively discharged to Mission Bay or to San Diego Bay. This varying discharge would have led to a variable supply of relatively coarse-grained sediment for the area of the Site. During the times when the river was flowing into San Diego Bay, it is likely that the entire eastern Mission Bay area was accumulating only the finer-grained silts and clays observed to be predominant in borings from that area.

The more porous and permeable coarse-grained layers would tend to form preferential pathways for the movement of groundwater. Lenses of coarse sediment formed in ancient stream channels, such as those occupied by the San Diego River prior to development of Mission Bay, would be likely to create a complicated pattern of subsurface pathways.

As interpreted from the geologic map prepared by Michael P. Kennedy (1975), the Site is underlain by Quaternary artificial fill. Based on observations of soil samples collected from the completed soil borings, the Site is underlain by hydraulic and imported fill that overlies native soils. The hydraulic and imported fill consists of black, brown, and grey very fine- to fine-grained sandy silts and clayey silts with trace organics and mica. The native soils present at the Site represent different depositional environments in the geological history of the Site, such as mudflats and channel sands.

7.1.2 Summary of Landfill History

7.1.2.1 Historical Conditions

The landfill is located in the southeastern corner of what is currently known as Mission Bay Park. The park area was formerly occupied by over 4,000 acres of sand flats and wetlands, and the San Diego River formerly crossed the current location of the landfill from south to north. A new river channel was constructed as part of the Mission Bay Park and the River now flows due west. Based on information gained from historical maps and aerial photographs, there was little development in the immediate area of the Site prior to the channelization and relocation of the San Diego River. Local developments included an airfield, a speedway, and a small residential subdivision.

7.1.2.2 Landfill Construction

Prior to and during landfill operations, the Site and the surrounding area were altered significantly, primarily due to the construction of Mission Bay and Mission Bay Aquatic Park. A berm of coarse sand estimated to be over 300 feet wide was created between the landfill and the bay. The former San Diego River Channel, which historically (pre-landfill) generally transected the Site and discharged to the bay in the area where the existing South Shores Boat Basin is located, was filled in with landfill waste. In addition, dredged material from the bay (intertidal mudflats) was used extensively in the landfill, which created a soil cap on the landfill. Post-landfill operations included the creation of a levee along the South Shore of Pacific Passage. In addition, the South Shores boat launching basin was excavated immediately north of the landfill boundary. To maintain the stability of the slope for the basin, a geomembrane liner stabilized with rip-rap was placed on the slope.

The Site was operated by the City of San Diego as a municipal landfill from 1952 to 1959; it received hydraulic fill from large- and small-scale dredging of Mission Bay from 1959 to 1969, and additional fill in the 1980s.

Initial operations at the landfill began in 1952, after the completion of the San Diego River flood control channel. The first refuse was placed at the landfill into east-west trending trenches excavated in sandy soils. Photographs from City files show that a dragline excavated deep narrow trenches and that a dozer was used to push and compact the refuse placed into the trenches.

Aerial photographs of the early landfill show that operations started west of the abandoned northwesterly flowing channel of the San Diego River. A platform of refuse and soil cover was constructed northward from the levee of the flood control channel, and eastward toward the old river channel. The old channel was filled and operations continued to move in an easterly direction along the levee and northeasterly across the existing sand flats. The former river channel is likely to represent a preferential pathway for the migration of groundwater through the buried waste toward the bay.

City records in 1954 indicate that the active area of the landfill would be expanded, allowing for operations at the western end during the dry summer months and at the more accessible eastern end during the winter. Aerial and ground photographs show that by 1956, the area of the landfill had been greatly expanded and that active operations appeared to be in progress at both ends of the Site. In 1957, the City's dredging operations began to have a significant impact in the area around the Site. A wide berm of relatively coarse sand dredged from Quivira Basin was constructed along the area designated to become the southern shore of Pacific Passage. This sand berm formed a topographic "high" that influenced the drainage in the South Shores area throughout the remainder of the landfill operations and for some time after closure of the landfill. In aerial photographs from late 1957, the topographic depression created south of the sand berm appears to have been subject to flooding.

From 1957 to late 1959, aerial and ground photographs show that operations continued at both ends of the landfill. Much of the central part of the Site appears to have been relatively inactive during this period, or to have been used mainly for stockpiling of materials. Photographs of operations at the western end of the Site show relatively wide north-south trending trenches and associated large soil stockpiles. Work along the eastern end of the Site appears to have been conducted along a relatively narrow, roughly north-south trench along the perimeter of the landfill.

The large-scale dredging of Mission Bay continued to affect the Site after the City's sanitary landfill ceased operations in 1959. Large quantities of saturated fine-grained hydraulic fill sediments were pumped into the closed basin of the South Shores area. Aerial photographs taken in 1961 appear to show the disposal of dark-colored materials from the dredging into the topographic depressions in the area of the Site.

These activities resulted in the presence of extensive layers of hydraulic fill across the entire South Shores area. The chemical characteristics of these hydraulic fill deposits are generally unknown, but the fill should be considered a potential source of contaminants, pending the results of soils testing. Limited sampling of surface soils was conducted during this assessment.

The large-scale dredging activities in Mission Bay were completed in 1961, but additional fill placement continued on an occasional basis into the 1980s. Although possible signs of grading activities are visible on the aerial photographs of this period, the exact locations and characteristics of the additional fill deposits are not known. More recent construction activities at South Shores caused additional modification to the area, especially in the vicinity of the boat basin where a portion of the northern sand berm was excavated to create the boat basin.

7.1.3 Surface Water Hydrology

The Site is bounded to the north by Mission Bay and to the south by the San Diego River Channel. Mission Bay experiences oceanic tides because it is open to the Pacific Ocean. It also receives storm water flows that primarily affect water quality rather than quantity.

The San Diego River Channel was constructed to contain the river, thus directing it west to the Pacific Ocean. The San Diego River drainage covers approximately 400 square miles and significant flood events occur within the watershed that ultimately discharge to the ocean. Tidal influences are observed in the river channel; however, the accumulation of sediment and beach sands at the river mouth limit tidal effects.

7.1.4 Hydrogeology

The flow of groundwater is hydraulically controlled by conditions within the San Diego River (to the south), and Mission Bay (to the north). Both are subject to tidal influences although tidal conditions within the San Diego River channel are reduced in magnitude due to the relative distance to the Pacific Ocean and the accumulation of sediment and beach sand at the mouth of the river.

SCS conducted a month-long monitoring of groundwater levels. Water levels were recorded at 10-minute intervals to observe the tidal influence on the wells. During the time of the SCS tidal study two large rain events (October 20 and 27, 2004) occurred that allowed for an opportunity to observe how flood events affected the groundwater regime at the Site. The groundwater elevation maps and data obtained during a flood event suggest that the area of the Site that is interpreted to be underlain by the former San Diego River channel is a preferential pathway of flow for groundwater beneath the Site. This is evident because this area of the Site displays the highest hydraulic gradient as well as transmitting the flood pulses the most efficiently. The increased gradients are also caused by the “short-cut” created by the South Shores Boat Basin.

The eastern and western sides of the Site display the lowest hydraulic gradient and took the most amount of time to facilitate the propagation of the flood pulses.

Water measurements taken at low tide from the drive points (Section 5.15) advanced within the sediment comprising the San Diego River flood basin to the south of the Site identified a downward hydraulic gradient that may be representative of groundwater recharge components of the groundwater regime. Conversely, water level measurements at low tide taken from the drive points advanced in sediments within Mission Bay immediately adjacent to the north side of the Site identified an upward hydraulic gradient representative of groundwater discharge into Mission Bay.

Vertical water quality parameter profiles were performed within 11 of the wells at the Site to assess stratification and the potential for isolation of contaminants by a halocline and the potential for pH-controlled mobility of metals. In general, pH, conductivity, and TDS values increased with depth while temperature and dissolved oxygen decreased with depth. It was observed that 2- to 8-foot-thick layer of buoyant, brackish groundwater is entering the Site from the San Diego River. The conclusion that a halocline is present in the groundwater regime of the Site was based on the observation of salinity values (represented as TDS) fluctuating with depth. A majority of the graphs provided in Appendix 5.15 demonstrate the presence of a halocline with a marked salinity increase at the interface of buoyant brackish groundwater above denser hypersaline groundwater. The presence of the halocline affects the movement of COPCs dissolved in groundwater by facilitating a majority of COPC transport within salinity specific groundwater zones in the saturated subsurface of the Site.

Groundwater levels beneath the Site are just above mean sea level, and hydraulic influences include the tidally influenced Mission Bay to the north and the San Diego River Channel to the south. While the mouth of the river channel is often filled with sand due to wave action, the river channel can be influenced by oceanic tides that cause water in the river to 'back up' at high tides. Tidal influences appear to constantly affect the groundwater elevation in all wells at the Site (except MBW7). Thus tidal influences cause water levels to rise and fall on a daily basis, with stronger influences occurring along Mission Bay. Groundwater generally flows to the north across the site, from the river to Mission Bay; however, short-term reversals of the overall flow pattern may occur along the Site margins during tidal events.

The two most tidally efficient monitoring wells at the Site are MBW2 and SCS4. The total dissolved solids that were reported from groundwater samples collected from these two wells are very similar to that of saline bodies of water. This suggests that the area of the Site containing these wells is in the highest degree of communication with the waters of the bay. The wells with the highest tidal lag appear to correspond directly with the wells distance from the bay, where higher distances produce a higher tidal lag. This translates into a larger time delay for tidal influences to affect the groundwater within these wells.

7.1.5 Landfill Containment

The Mission Bay Landfill was operated as a sanitary landfill consistent with procedures typically in use during the 1950s. The landfill was constructed within a basin formed during the construction of Mission Bay Park. The base of the landfill was constructed on native soils and hydraulic fill. It was not constructed on a liner system as is the current practice; however, waste was placed in excavated cells and regularly covered with soil. Currently the landfill is capped with 1.5 to 19.5 feet of soil (an average of 9.3 feet) as illustrated in Figure 6.2.

Laterally the landfill is contained on all sides. The southern boundary occurs south of Sea World Drive and is coincident with the northern levee of the San Diego River Channel. To the east and west are the excavation limits of the landfill and similar soil conditions occur. The northern limit of the landfill initially consisted of an approximately 300-foot-wide sand berm that was partially excavated to create the South Shores Boat Basin. The northern extent of the landfill along the boat basin consists of an engineered barrier system (see further details in Section 5).

7.2 Contaminant Sources and Contaminants of Potential Concern

The primary source of contaminants of potential concern (COPC) is landfill waste, which is reportedly up to 25 feet thick in some areas and is inferred to be located 10 feet below groundwater in other places (inferred from landfill daily logs and ground photograph interpretation).

Groundwater appears to be in direct communication with the landfill waste body throughout the length of the Site. The estimated elevations of the bottom of the landfill derived from the landfill waste thickness map (Figure 6.1), the landfill soil cover thickness map (Figure 6.2), and current topography (Figure 6.3) show that much of the base of the landfill is saturated. The groundwater at the Site is brackish to saline.

COPCs identified to date (either in laboratory data or reports of waste that went into the landfill) include metals such as mercury, arsenic, lead, and chromium; solvents including carbon tetrachloride, chloroform, bromoform, methylene chloride, diethyl ether, carbon disulfide, dichloroethane, vinyl chloride, phthalate compounds, and dichlorobenzene. MTBE (methyl tertiary butyl ether) and gasoline components (benzene, toluene, xylene) have also been detected in both surface water and groundwater.

COPCs in soil and sediment have been summarized in Section 6.3. These include metals such as arsenic, chromium, copper, vanadium, and zinc, and solvents such as acetone, 2-butanone (MEK), and methylene chloride, among others. Several polynuclear aromatic hydrocarbons (PAHs), semivolatile organic compounds (SVOCs), and pesticides have been detected in laboratory analysis, including benzo(a)pyrene, phthalate compounds, and DDT, among others.

7.2.1 Landfill Contents

Some of the waste at the Site is municipal refuse, but it is also reported to have waste that originated at aerospace or other local industrial firms, and from the U.S. military. Overall, it is expected that some of these wastes contained industrial chemicals, including metals, solvents, and industrial process residues that today are regulated as hazardous waste. Conflicting reports exist as to the quantity of hazardous waste that the landfill accepted, which is reported to have been mainly in drums.

7.2.2 Analytical Sampling: Surface Soils

Ten surface (4 to 12 inches below grade) soil samples were collected at the Site for laboratory analysis. Acetone was the only VOC analyte detected (147 µg/kg in sample S2-6”) above the laboratory detection limit (50 µg/kg) in the surface soil samples. Two PAH analytes (benzo[b]fluoranthene and chrysene) were detected in the surface soil samples above the laboratory detection limits. The reported concentrations of SVOCs, total cyanide, chlorinated herbicides, organochlorine pesticides, and PCBs were below the respective laboratory detection limits for all the surface soil samples.

The reported concentrations of Title 22 Metals in the surface soil samples were compared to the California Human Health Screening Levels (CHHSLs) for soil with commercial/industrial land use. All detectable arsenic concentrations in soil exceed the arsenic CHHSL. However, the CHHSL for arsenic is extremely low (0.24 mg/kg), even below the detection limit for arsenic of 0.25 mg/kg. Furthermore, natural background concentrations of arsenic in California range from 0.59 to 11 mg/kg, with an arithmetic mean concentration of 3.5 mg/kg (U.S. EPA, 2005). Thus, even naturally occurring background concentrations of arsenic significantly exceed the CHHSL. Both U.S. EPA and Cal-EPA policy is to not require cleanup to below natural background levels. Therefore, arsenic soil concentrations above the CHHSL but within the range of natural background would not be expected to require remediation.

7.2.3 Analytical Sampling: Subsurface Soils from Soil Borings

Twenty-four soil samples collected during the advancement of the 18 soil borings completed at the Site were selected for laboratory analysis. None of the analyzed soil borings samples were reported to contain detectable concentrations of SVOCs.

The reported concentrations of hexavalent chromium in soil samples collected from soil borings ranged from below laboratory detection limits (<0.100 mg/kg) to 0.21 mg/kg in soil sample B18-20’.

7.2.4 Analytical Sampling: Subsurface Soils from Monitoring Wells

Twenty-three soil samples collected during the advancement of the four monitoring wells completed at the Site were selected for laboratory analysis. None of the analyzed soil borings samples were reported to contain detectable concentrations of SVOCs except bis(2-ethylhexyl)phthalate, which was detected in soil sample SCS1-5' at 586 mg/kg.

The reported concentrations of hexavalent chromium in soil samples collected from soil borings ranged from below laboratory detection limits (<0.100 mg/kg) to 0.65 mg/kg in soil sample SCS3-20'.

7.2.5 Analytical Sampling: Landfill Gas

SCS conducted a landfill gas (LFG) emissions/migration assessment (EMA) to determine the type and amount of various chemical emissions from the Mission Bay Landfill. The EMA consisted of the collection of the following types of samples:

- Raw landfill gas samples from within the refuse prism
- Near-surface soil vapor samples from the cover of the Mission Bay Landfill
- Surface emissions samples.

Sampling was conducted over a 6-day period from May 25 through June 2, 2004 by SCS and H&P Mobile Geochemistry (H&P). Near-surface soil vapor samples were collected at the same location as the raw LFG sampling. These samples were used to identify and quantify the VOC concentrations within the cover of the Mission Bay Landfill for purposes of determining an attenuation factor to relate the estimated generation to the actual emissions through the cover of the Mission Bay Landfill.

The laboratory results indicated that the raw LFG samples contain methane, carbon dioxide, oxygen, and nitrogen as the main constituents. Trace amounts of the following constituents were also found in the LFG samples: ethane, hydrogen sulfide, 1,2-dichlorobenzene, 1,4-dichlorobenzene, methyl ethyl ketone (MEK), acetone, chlorobenzene, chlorodifluoromethane, dichlorodifluoromethane, dichlorofluoromethane, ethylbenzene, xylenes, butane, hexane, pentane, propane, trichloroethene, and vinyl chloride.

Relatively high methane concentrations remain in the landfill, ranging from 20 to 50% by volume. Comparison of Figures 6.2 and 6.4 shows that the area of methane concentration greater than 15% coincides with the area where the base of the landfill waste is below groundwater. For a more detailed discussion of the LFG sampling results please refer to Section 5.5.

The Air Pollution Control District (APCD) collected ambient air samples on April 14, April 18, and May 3, 2004 at the landfill property boundary from upwind, central, and downwind sample locations. Results from the laboratory analysis indicated that only

trace concentrations of volatile organic compounds were detected at the three sampling points. The concentrations were similar at each sampling point and the average results were similar to the ambient levels found in El Cajon and Kearny Mesa. The APCD concluded that localized hot spots of toxic compounds did not exist at the surface of the landfill.

On June 8, 2004, SCS performed integrated surface emissions monitoring on the areas with high field screening readings to assess the integrity of the landfill cover as an effective gas migration barrier. The laboratory results indicated that the air above the surface of the landfill was of typical composition. Trace amounts of VOCs were also detected in some samples, including 2-propanol, acetone, carbon disulfide, chloromethane, dichlorodifluoromethane, ethanol, ethylbenzene, xylenes, methylene chloride, propane.

7.2.6 Analytical Sampling: Sediment

Unconsolidated materials within Mission Bay and the San Diego River Channel may originate from the Site or from other areas within the watershed. Given the complex history of imported dredge materials used to construct Mission Bay, and the extensive watershed that drains into the bay, there are multiple potential sources of contaminated sediments and surface water in the bay or river. The results of sediment testing indicates that the reported concentrations of VOCs, SVOCs, total cyanide, chlorinated herbicides, and organochlorine pesticides were below the respective laboratory detection limits for all the sediment samples. Six PAH analytes (acenaphthene [<100 to $380\text{ }\mu\text{g/kg}$], anthracene [<2 to $2\text{ }\mu\text{g/kg}$], naphthalene [<50 to $71\text{ }\mu\text{g/kg}$], fluoranthene [<5 to $30\text{ }\mu\text{g/kg}$], phenanthrene [<4 to $40\text{ }\mu\text{g/kg}$], and pyrene [<10 to $130\text{ }\mu\text{g/kg}$]) were detected in the sediment samples above the laboratory detection limits.

The reported concentrations of Title 22 Metals in sediment samples were compared to the California Human Health Screening Levels (CHHSLs) for soil with commercial/industrial land use. All detectable arsenic concentrations in sediment exceed the arsenic CHHSL. However, the CHHSL for arsenic is extremely low (0.24 mg/kg), even below the detection limit for arsenic of 0.25 mg/kg . Furthermore, natural background concentrations of arsenic in California range from 0.59 to 11 mg/kg , with an arithmetic mean concentration of 3.5 mg/kg (U.S. EPA, 2005). Thus, even naturally occurring background concentrations of arsenic significantly exceed the CHHSL. Both U.S. EPA and Cal-EPA policy is to not require cleanup to below natural background levels. Therefore, arsenic sediment concentrations above the CHHSL but within the range of natural background would not be expected to require remediation. No other exceedances of the remaining analyte CHHSLs were observed.

7.3 Potential Release Mechanisms/Secondary Sources

There are two basic scenarios to consider for the landfill where a release can occur that include either the existing condition or, in the event of construction, on or within the landfill. Both are addressed in the health risk assessment (Section 8).

In general, the potential for human and ecological exposure to hazardous substances depends on whether a known source can lead to exposure via a number of different exposure pathways. The potentially complete exposure pathways include air, groundwater, surface and fill soils, and sediments in Mission Bay or within the San Diego River Channel. There are two primary sources: the former landfill, and potentially contaminated fill soils used to construct this area of Mission Bay and also used to cover the landfill following cessation of operations.

A release can occur from the landfill in a number of ways. The following descriptions are organized in terms of the sub-portions of the landfill as described in the Site assessment.

7.3.1 Surface Soils

Surficial soils are available for direct contact, resulting in dermal contact and/or incidental ingestion of contaminants, or may be mobilized by wind or water erosion. Wind erosion can cause respirable particles to occur on or adjacent to the Site, and wind and water erosion can cause surface soils to be deposited as sediments in the adjacent aquatic habitats or within recreational areas of Mission Bay Park.

Human and ecological exposure to surface soils is expected. These soils were primarily derived from dredging of Mission Bay and analytical testing was conducted by SCS for this report (Section 5.8).

7.3.2 Vapors and Landfill Gases

Gas migration from the landfill can potentially affect both human and ecological receptors. VOCs, for example chlorinated solvents, are known to occur in the former landfill. Methane, hydrogen sulfide, and other biogenic gases typically form in a landfill, and will also form in a wetlands/marsh environment as a consequence of microbial degradation of organic matter under anaerobic conditions. This will contribute to the generation of gases within the local sediments and within the former landfill.

7.3.3 Groundwater

Dissolution and transport of solutes from fill soils, and from solid and liquid wastes deposited in the former landfill, is known to occur. In general, groundwater flows from the San Diego River Channel north across the Site and into Mission Bay.

Discharge of groundwater from beneath the Site to the San Diego River and Mission Bay is the primary transport mechanism for COPCs dissolved in groundwater to exit the Site.

Incidental worker exposure to groundwater is possible should invasive activities occur. This could include accidental ingestion, exposure to vapors associated with groundwater, or dermal exposure. Engineering controls and personal protective equipment (PPE) are assumed prudent and necessary for anyone involved in excavation into the landfill given the potential for hazardous substances to occur.

Burrowing animals or plant roots may potentially encounter groundwater within or adjacent to the landfill footprint.

7.3.4 Interior Content of the Landfill

Subsurface fill soils may contribute to groundwater contamination as described above. Direct exposure to subsurface soils, groundwater, and gases will occur if excavation is conducted.

7.4 Exposure Pathways

Both human and ecological receptors can come into contact with hazardous substances via inhalation (or respiration), ingestion (or other forms of internal uptake), or dermal (direct) exposure. These three mechanisms are noted in the table for each of the exposure pathways (Figure 8.1).

Potential human and ecological receptors (i.e., those potentially exposed to hazardous substances or conditions associated with the Site) are also identified in Figure 7.1. For humans, the current recreational use of the Site is illustrated. Additional scenarios will be evaluated in the risk assessment (Section 8). Three ecological habitats occur that include the saltwater Mission Bay, fresh to brackish waters of the San Diego River Channel, and the terrestrial portion of the Site. The purpose of the biological resources survey was to directly support the ecological scoping assessment. Specific species of flora and fauna were identified and the health of their habitat was evaluated.

Recreational exposures to surface water and sediments occur regularly within Mission Bay. Direct exposure to surface (fill) soils across the Site also occurs. The San Diego River is not considered a recreation area. The river channel is a known sensitive habitat. The biological survey provides additional information regarding the nature of the habitat.

Short-term worker exposures to surface waters and sediments in Mission Bay and in the San Diego River are possible, as are exposures to surface soils. Given the multiple potential sources of contamination in the urban environment, the landfill is just one of many potential contributors to the water quality of Mission Bay.

7.5 *Human and Ecological Health Risk Assessments*

Section 8 includes the Human Health Risk Assessment. The Ecological Risk Assessment is discussed in Section 9. The results are not repeated in this SCM and the reader is referred to the summary discussions included in each section.

8.0 HEALTH RISK ASSESSMENT

8.1 Introduction

This human health risk assessment (HRA) describes the evaluation of potential health risks associated with the Mission Bay (MB) landfill. The methods used were selected first to be consistent with recommendations of the California regulatory agencies primarily responsible for reviewing risk assessments for contaminated sites in California. These agencies include the California Department of Toxic Substances Control (DTSC) and the California Office of Environmental Health Hazard Assessment (OEHHA). Comments on the risk assessment methods were solicited directly from OEHHA in the form of a technical memorandum from SCS (SCS, 2005). The OEHHA comments (OEHHA, 2004 and 2005) were incorporated in the risk assessment after review and approval by the Mission Bay Technical Advisory Committee (TAC). If risk guidance was not available from the California agencies for some aspect of the risk assessment, recommendations of the United States Environmental Protection Agency (U.S. EPA) were used.

A unique aspect of this HRA is the explicit consideration and application of the “precautionary principle” (PP). Consideration of the PP in the development of this risk assessment was requested by the TAC. The precautionary principle was originally articulated at the 1998 Wingspread conference in Racine, Wisconsin as follows (Montague, 1998):

“When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically.”

Thus, in addition to adhering to the generally conservative (health protective) risk assessment methods recommended by state and federal agencies, this HRA adopts even more conservative approaches for certain aspects of the risk assessment consistent with a precautionary approach to health risk assessment. These particular aspects of the risk assessment are noted as such. In addition, a very important component of the PP is the identification of uncertainties associated with public health decision-making. Consistent with the PP the uncertainties associated with this HRA and the general effect of those uncertainties on the risk estimates are described in Section 8.4.

Based on discussions with the TAC the following receptor populations were selected for evaluation in this HRA:

- Adult and child recreational user
- Child swimmer
- Commercial worker
- Construction worker
- Homeless or transient adult

The following exposure pathways were evaluated as appropriate depending on the receptor population:

- Incidental soil ingestion
- Dermal contact with soil
- Inhalation of soil particulates in outdoor air
- Inhalation of volatiles in outdoor air
- Inhalation of volatiles in indoor air (vapor intrusion)
- Dermal contact with surface water
- Incidental ingestion of surface water

This HRA consists of four parts:

- Data sources and evaluation
- Exposure assessment
- Risk characterization
- The precautionary principal and uncertainty analysis
-

Each of these parts is described in detail below.

8.2 Data Sources

Data used in this HRA were obtained either from very recent investigations conducted by SCS and described in detail elsewhere in this report, or from a site investigation report prepared by Woodward-Clyde (Woodward-Clyde, 1993). All data from the Woodward-Clyde report were used except for the following:

- Soil VOC data
- Soil vapor survey data
- Groundwater data

The data listed above were considered to be obsolete due to the fact that it is volatile chemical data and therefore would be expected to change significantly over the years since 1993. In the case of the groundwater data, newer data collected by SCS were used instead.

Table 8.1 lists the analytical methods used by SCS to determine chemical contaminants in soils, soil vapor, and groundwater. Virtually all conceivable chemical analyte groups were examined at the MB landfill. The numbers and locations of samples collected from each media are described in detail elsewhere in this report.

8.3 Exposure Assessment

Quantitative assessment of human exposure to chemicals in the environment involves the following steps:

- Estimating the chemical concentrations or “exposure point concentrations” (EPCs) in the environment (e.g., soil, water, air) to which individuals may be exposed.

- Identifying chemicals of potential concern (COPC) (chemicals most likely to present a potential health risk).
- Determining how, and with what frequency and magnitude, individuals may contact chemicals in the environment (exposure scenario).

8.3.1 Calculation of Exposure Point Concentrations

Exposure point concentrations (EPCs) are the concentrations of chemical in soil, water, or air that are used to calculate human health risks. Consistent with U.S. EPA risk assessment guidance (USEPA, 1989), the EPC for a chemical was the lesser of the 95 percent upper confidence limit of the arithmetic mean (95UCLM) or the maximum concentration. For the purposes of the EPC calculation, nondetect values were assigned a value of one-half the sample quantitation limit (SQL), or the practical quantitation limit (PQL) if the SQL was equal to the PQL. These decision rules are consistent with the DTSC guideline document, *Use of Soil Concentration Data in Exposure Assessments* (DTSC, 1996).

In addition to the above guidelines, calculation of the soil EPCs requires specifying the depth interval from which soil concentrations are used to calculate the EPCs. For the MB HRA a soil depth interval of 0-10 ft was used for the commercial worker and construction worker receptors and a soil depth interval of 0-5 ft was used for the recreational user and transient. A deeper soil interval is used for the commercial worker and the construction worker due to the greater likelihood of contact with deeper soils. These soil depth intervals are typically required for these population receptors by DTSC and OEHHA for California site risk assessments. EPCs were calculated for all chemicals showing at least one unqualified detection.

All raw data used in the HRA are summarized in Appendix 8.1. Statistical summaries of the data used to determine the EPCs are provided in Appendix 8.2. The final EPCs for soils, landfill gas, soil vapor, and groundwater are shown in Tables 8.2, 8.3, 8.4, and 8.5, respectively.

8.3.2 Identification of Chemicals of Potential Concern

“Chemicals of Potential Concern” or COPCs, are the subset of chemicals at a site which may potentially present a health risk. Frequently at a site, many chemicals are detected, however, the levels of some of these, particularly naturally occurring inorganic chemicals, may be comparable to, or below, natural background concentrations. Such chemicals are not of health concern and are typically excluded from further evaluation. However, consistent with application of the PP to the MB HRA, all detected chemicals were included in this HRA. This approach is expected to result in an overestimate of risks for the MB landfill since it includes the risks associated with naturally occurring background levels of inorganic chemicals, particularly arsenic. The complete list of COPCs is shown in Tables 8.3.1 and 8.3.2 (in Appendix 8.3).

8.3.3 Description of Exposure Scenarios, Receptor Populations, and Exposure Pathways

In order to estimate human exposure to contaminants, assumptions must be made regarding how an individual will contact the contaminants and with what frequency. These exposure patterns are collectively referred to as an exposure scenario. The exposure scenario assumptions used depend on whether a child or adult receptor is exposed and the future use of the property, for example, residential, commercial/industrial, or recreational.

Because the subject site is a landfill, there is no potential for residential construction on the site. Therefore, a residential receptor population is not applicable. On the other hand, the site area is used routinely by individuals for walking, jogging, and bicycling. Both adults and children may participate in these activities. In addition, landfill or park maintenance personnel may periodically visit the site. In the course of these activities these individuals may come into contact with surface soils of the landfill through direct dermal contact or through inadvertent ingestion of soils. In addition, individuals may inhale contaminants suspended in air by wind erosion. There is also some limited potential for individuals to inhale chemicals which may have volatilized from the landfill. The TAC noted that there may be plans for the construction of a swim team clubhouse on the site. Therefore, potential risks to a construction worker and a child swimmer were also evaluated. For the child swimmer, risks associated with dermal contact to landfill contaminants in Mission Bay surface water were of particular concern. Because of the difficulty in determining what contaminants in Mission Bay would be attributable to the landfill specifically, a very conservative assumption was made that the concentrations of landfill contaminants in Mission Bay would be the same as in groundwater under the landfill. In reality, it is much more likely that landfill contaminants moving into the bay from groundwater would be diluted many-fold, perhaps by several orders of magnitude. Finally, it was noted that transients live on the site from time to time and for varying periods. Therefore, risks to a hypothetical transient were also evaluated.

Based on the above rationale, the following receptor populations and exposure pathways were evaluated in the HRA:

8.3.3.1 Adult and Child Recreational User (e.g., Walker or Bicyclist)

- Soil ingestion
- Dermal contact with soil
- Inhalation of particulate-phase contaminants in outdoor air from resuspended soil
- Inhalation of vapor-phase contaminants in outdoor air

8.3.3.2 *Commercial Worker (e.g., Park Maintenance Worker)*

- Soil ingestion
- Dermal contact with soil
- Inhalation of particulate-phase contaminants in outdoor air from resuspended soil
- Inhalation of vapor-phase contaminants in outdoor air
- Inhalation of vapor-phase contaminants in indoor air (vapor intrusion)

8.3.3.3 *Swimmer*

- Dermal contact with surface water
- Incidental ingestion of surface water

8.3.3.4 *Construction Worker*

- Soil ingestion
- Dermal contact with soil
- Inhalation of particulate-phase contaminants in outdoor air from resuspended soil
- Inhalation of vapor-phase contaminants in outdoor air

8.3.3.5 *Transient*

- Soil ingestion
- Dermal contact with soil
- Inhalation of particulate-phase contaminants in outdoor air from resuspended soil
- Inhalation of vapor-phase contaminants in outdoor air

Exposure assumptions consistent with a reasonable maximum exposure scenario (RME) were used in this risk assessment. The RME is considered an upper bound estimate of the chemical exposure that may occur to an individual. The use of RME exposure assumptions is expected to conservatively estimate health risks for the receptor population and is consistent with the PP.

8.3.4 *Conceptual Site Model*

The relationships between the exposure pathways and population receptors described above are graphically summarized in the conceptual site model shown in Figure 8.1.

8.3.5 *Calculation of Chronic Daily Intakes*

Quantitative estimates of chemical exposure are referred to as the Chronic Daily Intake (CDI). The CDI can be thought of as the average amount of chemical expected to be taken into the body from a particular exposure pathway each day over a long period of time. CDIs for each exposure pathway were calculated using the equations

and assumptions shown in detail below. The equations below indicate the general form of the CDI calculation for each pathway. Model parameter values differ depending on whether the COPC is a carcinogen or noncarcinogen and depending on whether the receptor is the adult or child resident. A complete list of the various exposure parameters that were used in the following calculations is shown in Table 8.6.

8.3.5.1 Soil Ingestion

Contaminants in soil may be inadvertently ingested through hand-to-mouth contact. The CDI for this pathway was calculated as follows:

$$CDI = \frac{CS \times CF_s \times IR_s \times EF \times ED}{BW \times AT}$$

where:

- CDI = Chronic Daily Intake (mg/kg/day)
- CS = Chemical concentration in soil (mg/kg)
- CF_s = Conversion factor for soil (1E-06 kg/mg)
- IR_s = Soil ingestion rate for adult or child (mg/day)
- EF = Exposure frequency (days/year)
- ED = Exposure duration for adult or child (years)
- BW = Body weight for adult or child (kg)
- AT = Averaging time (days)

CS is the soil EPC calculated as described above. The soil ingestion rate, IR_s, is the average amount of soil incidentally or inadvertently ingested by an individual (adult or child) on an average day. The exposure frequency, EF, corresponds to the number of days per year an individual would be expected to ingest soil. The exposure duration, ED, is the total number of years an individual would be expected to reside on, or visit the site. The body weight, BW, is the average body weight for an adult or 6-year-old child. The averaging time, AT, is the total number of days over which the exposure is averaged in the life of the individual. For carcinogens, this value is always 70 years or 25,550 days. However, for noncarcinogens the value for AT depends on the receptor population (see Table 8.6).

8.3.5.2 Inhalation of Particulate-Phase Chemicals in Outdoor Air

Individuals may be exposed to contaminants in soil via the inhalation of resuspended soil particulates. Consistent with U.S. EPA guidance (USEPA, 2005), this pathway was evaluated only for nonvolatile compounds (defined as compounds with a molecular weight greater than 200 g/mole and a Henry's Law constant less than 1.0E-05 atm-m³/mol [USEPA, 2005]). The CDI associated with this pathway was calculated as follows:

$$CDI = \frac{\frac{CS}{PEF} \times InhR \times EF \times ED}{BW \times AT}$$

where:

- CDI = Chronic Daily Intake (mg/kg/day)
- CS = Chemical concentration in soil (mg/kg)
- PEF = Particulate emission factor (m³/kg)
- InhR = Inhalation rate for adult or child (m³/day)
- EF = Exposure frequency (days/year)
- ED = Exposure duration for adult or child (years)
- BW = Body weight for adult or child (kg)
- AT = Averaging time (days)

The particulate emission factor, PEF, is a conversion factor used to convert a soil contaminant concentration to an airborne particulate contaminant concentration (USEPA, 2005).

8.3.5.3 *Inhalation of Vapor-Phase Chemicals in Outdoor Air*

Volatile chemicals may be released from a landfill due to the methane generation within the landfill. The upwardly moving methane current has the effect of sweeping volatile chemicals along with it to the ground surface. A transport model was used to quantify the rates of volatile release from the landfill and the resulting ambient air concentration to which individuals may be exposed. This modeling is described in detail in Appendix 8.6.

8.3.5.4 *Inhalation of Vapor-Phase Chemicals in Indoor Air (Vapor Intrusion)*

When buildings are constructed over soils containing volatile chemicals there is some risk of vapor intrusion into the overlying structure. Vapors may enter the building through cracks in the foundation slab. When this happens, individuals working or residing in the building may breathe the vapors. The latest DTSC version of the Johnson and Ettinger (JE) vapor intrusion model (Soil Gas Screening Model, last modified January, 2005) was used to estimate risks due to air contaminants within a hypothetical commercial building. The DTSC model does not allow for estimation of the actual CDI for this pathway, instead model output is provided in terms of the predicted indoor air concentration and risk estimates (cancer risk for carcinogens or the hazard quotient for noncarcinogens). These results were incorporated in the risk characterization section of the RA report. This pathway was evaluated for the adult commercial worker. Default exposure parameters were used to conduct the modeling with the exception of the parameters shown in Appendix 8.5. Appendix 8.5 also includes sample modeling output of the JE model for 1,2-dichlorobenzene.

8.3.5.5 Dermal Contact with Soil

Dermal absorption of chemicals in soil may occur when soil particles make contact with, and adhere to the skin during outdoor activities. The CDI for the dermal absorption pathway was calculated as follows:

$$CDI = \frac{CS \times CF_s \times SA_s \times AF \times ABS \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg/day)
CS	=	Chemical concentration in soil (mg/kg)
CF _s	=	Conversion factor for soil (1E-06 kg/mg)
SA _s	=	Skin surface available for contact with soil for adult or child (cm ²)
AF	=	Soil-to-skin adherence factor (mg/cm ² /event)
ABS	=	Fraction of chemical dermally absorbed (unitless)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration for adult or child (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

The skin surface, SA_s, refers to the expected amount of an individual's skin surface available for contact with soil. The soil-to-skin adherence factor, AF, is the amount of soil adhering to the skin surface after a soil contact event. The fraction of chemical dermally absorbed, ABS, is the fraction of chemical adhering to the skin which is expected to be absorbed across the skin into the body. Chemical-specific ABS values were obtained from DTSC (1994) if available; otherwise a default value of 0.01 or 1% was assumed for inorganic chemicals and 0.1 or 10% for organic chemicals (DTSC, 1994).

8.3.5.6 Dermal Contact with Surface Water

This exposure pathway was evaluated for the child swimmer only. Swimmers may absorb chemicals from surface water through the skin. In general, absorption is greatest for organic chemicals. The CDI for this pathway was calculated as follows:

$$CDI = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF_w}{BW \times AT}$$

CDI	=	Chronic Daily Intake (mg/kg/day)
CW	=	Chemical concentration in water (mg/L)
SA _s	=	Skin surface available for contact with water (cm ²)
PC	=	Chemical-specific dermal permeability coefficient (cm/hour)
EF	=	Exposure frequency (days/year)

ED	=	Exposure duration for adult or child (years)
CF _w	=	Volumetric conversion factor for water (1 liter/1000 cm ³)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

Note that it was extremely conservatively assumed that the surface water concentration was the same as the groundwater concentration. Chemical-specific permeability coefficients were obtained from U.S. EPA (USEPA, 2004).

8.3.5.7 *Ingestion of Surface Water*

It is typical for swimmers to accidentally ingest some small amount of water while swimming. The child swimmer exposure via this pathway was calculated as follows:

$$CDI = \frac{CW \times IR_{sw} \times SD \times EF \times ED}{BW \times AT}$$

CDI	=	Chronic Daily Intake (mg/kg/day)
CW	=	Chemical concentration in water (mg/L)
IR _{sw}	=	Water ingestion rate for child per hour of swimming (L/hour)
SD	=	Swimming duration (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration for adult or child (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

As in the case for the dermal pathway, the surface water concentration was very conservatively assumed to be the same as the groundwater concentration. Swimming duration (SD) was assumed to be 2 hours/day with an exposure frequency (EF) of 60 days per year (5 days/week for 3 months). Published data regarding the amount of water typically ingested during swimming is not available, however, the U.S. EPA assumes a value of 0.05 L/hour for adults (USEPA, 1989). For children a lesser value is reasonable and a value of 0.025 L/hour was assumed.

8.4 *Risk Characterization*

The health risks of a chemical are quantified in terms of non-cancer risks as well as carcinogenic risks if the chemical is considered a carcinogen. Non-cancer health risks refer to all other adverse health effects besides cancer. Carcinogenic chemicals may present non-cancer health risks in addition to cancer risks, therefore the potential for both types of effects must be evaluated for carcinogens. Health risks associated with lead and exposure to the common landfill hazard gases methane and hydrogen sulfide were also evaluated.

8.4.1 Non-Cancer Risks

The risk of non-cancer health effects is evaluated by comparing the CDIs for each exposure pathway to the U.S. EPA Reference Dose (RfD). The RfD is defined by U.S. EPA as "An estimate of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" (USEPA, 1989). The risk of non-cancer health effects is expressed quantitatively as the ratio of the CDI to the RfD. This ratio is termed the Hazard Quotient (HQ). For example, in the case of an oral or ingestion exposure (such as soil ingestion):

$$HQ = \frac{CDI_{oral}}{RfD_{oral}}$$

An HQ value greater than 1 indicates that the chemical exposure exceeds the level considered safe for long-term exposure by U.S. EPA.

In most cases, exposure from additional routes of exposure must be considered (dermal and inhalation), and the above equation is modified as follows:

$$HQ = \frac{CDI_{oral}}{RfD_{oral}} + \frac{CDI_{inh}}{RfD_{inh}} + \frac{CDI_{dermal}}{RfD_{oral}}$$

An HQ value greater than 1 indicates that the daily intake of chemical via all routes of exposure exceeds U.S. EPA safe levels for long-term exposure as defined by the RfD. Since U.S. EPA has not developed RfDs for the dermal exposure route, the oral route RfD is used to evaluate exposure via the dermal pathways.

RfDs used to calculate non-cancer risks were generally obtained from the U.S. EPA Integrated Risk Information System (IRIS). However, where an inhalation Chronic Reference Exposure Levels (RELs) (the California equivalent of an inhalation RfD) was available, the REL was used in lieu of the U.S. EPA inhalation RfD. This usually required a unit conversion from $\mu\text{g}/\text{m}^3$ for the inhalation REL to $\text{mg}/\text{kg}/\text{day}$ for an inhalation RfD. If an RfD was not available from the IRIS database or a State of California source then it was obtained from the following sources, in order of preference:

- U.S. EPA Region IX Preliminary Remediation Goal document (USEPA, 2005)
- The U.S. EPA Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997)

RfDs used to estimate non-cancer risks are shown in Tables 8.3.1 and 8.3.2 (in Appendix 8.3) for inorganic and organic COPCs, respectively.

CDIs and HQ values for all COPCS, potentially exposed populations, and exposure pathways are contained in Appendix 8.4, Tables 8.4.1 (commercial worker), 8.4.3 (construction worker), 8.4.5 (adult recreational user), 8.4.7 (child recreational user), 8.4.9 (swimmer), and 8.4.10 (transient). Non-cancer risk conclusions are discussed below in Section 8.4.2.

8.4.2 Cumulative Non-Cancer Risk

It is possible for the total HQ (for all pathways) for each contaminant at a site to be less than 1 but still present a potential for adverse noncarcinogenic effects. This can happen from the cumulative effects of contaminants that have a similar toxic mechanism and/or target organ. Although each contaminant exposure level may be acceptable when considered separately, the total cumulative effect of similarly acting toxicants can create a potential for an adverse effect. To ensure that the cumulative noncarcinogenic risk from multiple similarly acting contaminants is adequately considered, the total HQs across all contaminants are summed to obtain a Hazard Index (HI) as follows:

$$HI = HQ_1 + HQ_2 + HQ_3 \dots + HQ_n$$

This is a conservative first step in the analysis of cumulative effect potential because it disregards the specific mechanism of toxicity or target organ. In other words, it assumes that all contaminants act by a similar mechanism of action or have a similar toxic effect when in fact they may not. If the resulting cumulative HI using this conservative approach is greater than 1 a more refined analysis can be conducted. In the refined analysis, referred to by U.S. EPA as a “segregation of hazard indices” (USEPA, 1989), the COPCs are divided into subgroups based on similarity of effect. A cumulative HI is then calculated for each subgroup. If an HI of greater than 1 is still obtained for one of the subgroups, then the subgroup may be further classified based on mechanism of toxicity, and the subgroup HI values recalculated.

HI values exceeded the negligible risk threshold of 1 for the construction worker population only (Table 8.7). The HI value for the construction worker population was 4 with deep soil mercury concentrations contributing virtually all of the non-cancer risk (Table 8.7). Direct contact with soil through incidental soil ingestion and dermal contact are the primary mechanisms of exposure to mercury. Table 8.1.4 (Appendix 8.1) shows that a maximum mercury concentration of 2,917 mg/kg was detected at 10 ft. Another sample at 10 ft showed mercury at 2,077 mg/kg. These two mercury samples are the primary contributors to non-cancer risk for the construction worker. Note that no mercury was detected during the recent investigations by SCS, and these risks are based on concentrations of mercury detected during historical investigations conducted by Woodward-Clyde.

8.4.3 Lead Risks

Health risks associated with lead exposure are not evaluated using the RfD approach described above. Instead, lead health risks are evaluated based on the expected blood lead concentration that will result from exposure. The DTSC has developed a special model to predict blood lead concentrations and assess health risks associated with blood lead. This model is called ALeadspread® and it is the required model for evaluating lead risks in the state of California (<http://www.dtsc.ca.gov/ScienceTechnology/ledspread.html>). Health risks due to lead exposure were assessed using the latest version of this model (Leadsread 7). Consistent with DTSC policy, the 99th percentile blood lead concentration was considered to be the cutoff for acceptable risks. That is, acceptable lead levels in soil for any given exposure scenario are defined as those which produce a blood lead no greater than 10 µg/deciliter (dl) in 99 percent of the exposed population (adult and child). The Leadsread 7 model output is provided in Appendix 8.7 in Tables 8.7.1, 8.7.2, 8.7.3, and 8.7.4 for the commercial worker, construction worker, adult and child recreational user, and transient, respectively. Calculated blood lead levels were all below the safe threshold of 10 µg/dl for all receptor populations, indicating that health risks associated with lead at the MB landfill are negligible.

8.4.4 Hazard Gases

Two hazard gases were analyzed at the MB landfill: methane and hydrogen sulfide. The methods and locations are described elsewhere in this report. Methane has a very low acute toxicity, however at very high concentrations it can act as an asphyxiant by diluting the oxygen content of air (Olson, 1999). This is most likely to occur in situations where there is poor ventilation, for example indoors, or in outdoor confined space situations (e.g. trenches, pipes, sumps, etc.). The main hazard associated with methane is that it is explosive. The lower explosive limit (LEL) for methane is 5% in air. The upper explosive limit (UEL) is 15% in air. Concentrations between the LEL and UEL are explosive, concentrations below the LEL and above the UEL are not. The San Diego County Department of Planning and Land Use Building Department considers methane in soil gas to be a cause for concern if it exceeds 10% of the LEL or 0.5% in air. Unlike methane, hydrogen sulfide has a very high acute toxicity and is rapidly acting (Olson, 1999).

Soil vapor samples collected at the MB landfill by SCS from May to June 2004 were analyzed for methane and hydrogen sulfide (Table 8.8). Methane concentrations in soil vapor ranged from below the detection limit to 57%, with an average of approximately 21%. These values substantially exceed the concern level of 0.5% established by San Diego County. However, a walkover survey showed that methane is virtually undetectable in ambient air at the site (Table 8.9). Thus, even though concentrations of methane in soil vapor are very high, these levels are rapidly diluted to undetectable levels after leaving the ground. Thus, methane concentrations in soil gas, while presenting a construction hazard due to explosion potential, do not present a hazard to individuals walking over the landfill.

Hydrogen sulfide concentrations in soil gas ranged from below the detection limit to 21 ppm, averaging approximately 1 ppm. For comparison, the Threshold Limit Value - Short Term Exposure Limit (TLV-STEL) for hydrogen sulfide, defined as a 15-minute, time-weighted average which should not be exceeded at any time during a working day, is 10 ppm. The Threshold Limit Value - Time Weighted Average (TLV-TWA) of hydrogen sulfide, defined as the average concentration for a normal 8-hour working day and a 40-hour working week, to which nearly all workers may be repeatedly exposed day after day, without adverse effect is 15 ppm. Thus, since soil gas concentrations of hydrogen sulfide are still well below safe worker exposure levels, ambient air concentrations of hydrogen sulfide in air over the landfill would be expected to be substantially lower through dilution, as in the case for methane. However, it should also be noted that the limited soil gas survey conducted as part of the site characterization does not rule out the possibility that pockets of much higher concentrations of hydrogen sulfide may exist in the landfill. This hydrogen sulfide could be released suddenly in large amounts during construction, resulting in a hazard to construction workers.

8.4.5 Cancer Risks

Cancer risks are calculated by multiplying the total CDI for all exposure pathways for each route of exposure by the route-specific Cancer Slope Factor (CSF) as follows:

$$\text{Cancer Risk} = \text{CSF} \times \text{CDI}$$

Cancer risks were summed across all exposure pathways for all carcinogens to arrive at a total increased lifetime cancer risk for each receptor population.

CSFs used to calculate cancer risks were obtained preferentially from State of California sources (usually the OEHHHA Toxicity Criteria Database). If a CSF for a particular chemical was not available from a State of California source then it was obtained from the following sources, in order of preference:

- The U.S. EPA Integrated Risk Information System (IRIS) (accessed via the U.S. EPA website).
- U.S. EPA Region IX Preliminary Remediation Goal document (USEPA, 2005).
- The U.S. EPA Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997b).

CSFs for inorganic and organic COPCs are shown in Appendix 8.3, Tables 8.3.1 and 8.3.2, respectively.

CDIs and cancer risk estimates for all COPCs, potentially exposed populations, and exposure pathways are contained in Appendix 8.4, Tables 8.4.2 (commercial worker), 8.4.4 (construction worker), 8.4.6 (adult recreational user), 8.4.8 (child recreational user), 8.4.10 (swimmer) and 8.4.12 (transient). A summary of cumulative cancer risks for each receptor population is shown in Table 8.7. The highest cumulative cancer risks were for the commercial worker and child recreational user with values of about $2\text{E-}05$. By comparison, the negligible cancer risk threshold for California risk assessments is $1\text{E-}06$. Cumulative cancer risks for all other receptor populations also exceed the $1\text{E-}06$ cancer risk threshold. However, it should be noted that by far the main contributor to this increased cancer risk was arsenic occurring at values generally within the range of naturally occurring background levels. This is true for all other receptor populations as well (Table 8.7). The most important exposure pathways contributing to the risk are incidental soil ingestion and dermal contact with soil (Table 8.7). The soil EPC for arsenic at the landfill is 10 mg/kg and the mean concentration was 6.3 mg/kg. A study of arsenic concentrations in 50 native California soils conducted by the University of California-Riverside found that background concentrations range up to 11 mg/kg (Bradford, 1996). A DTSC study of arsenic background concentrations in southern California (Los Angeles area) concluded that if all site samples are less than 11.3 mg/kg then arsenic can be eliminated as a COPC in the risk assessment. All surface and shallow soil concentrations (less than 10 feet bgs) of arsenic at the MB landfill were less than 10 mg/kg, so arsenic concentrations to which virtually all site visitors might be exposed are below the DTSC arsenic background guideline. The maximum soil concentration of arsenic detected was 60 mg/kg. Another soil sample had a concentration of 45 mg/kg. However, both of these samples were detected at 10 feet bgs (Appendix 8.1, Table 8.1.4). Because of the depth of these samples they pose a potential risk only to construction workers. Construction on the site is unlikely due to the high concentrations of methane present in landfill gas (see Section 8.3.4).

8.5 The Precautionary Principle and Uncertainty Analysis

Although the basic concept underlying the Precautionary Principle (PP) has been around for years in the form of such adages as, “Better safe than sorry,” “Look before you leap,” and “Be careful,” it was only recently articulated formally as an alternative paradigm for evaluating activities which may adversely impact human health or the environment. In 1998 a diverse international group of scientists, government officials, lawyers, labor representatives, and grass-roots environmental activists met at the Wingspread Conference Center in Racine, Wisconsin to define the PP. The meeting resulted in the following “Wingspread Statement on the Precautionary Principle”:

“When an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.”

In other words, if some activity (or for example, a chemical exposure or use) may potentially pose a threat to the environment or human health, preventative action should be taken even if there is some uncertainty regarding that threat.

To the best of our knowledge the PP has not been formally implemented in any contaminated site risk assessment to date. Nor has any state or federal agency issued any guidance indicating how the PP would be implemented in a contaminated site risk assessment. Therefore, we are left to our own devices to formulate a reasonable approach for doing so. As a starting point, a review of the published literature indicates a general consensus regarding the four components of PP implementation in a given situation (Montague, 1998; Tickner and Raffensperger, 1999):

1. Exploring alternatives to the proposed, and potentially harmful, action
2. Placing the burden of proof regarding the relative safety of the proposed action on the proponents of the activity
3. Setting and working toward goals that protect human health and the environment
4. Increasing public participation and transparency to the entire activity review process.

The four items listed above indicate a focus on new projects or proposed activities as opposed to existing projects, such as the MB landfill. In other words, the PP, as originally articulated, is really best suited for evaluating the impacts of proposed projects/activities. For example, we are not evaluating whether a landfill should be constructed or what alternatives to a landfill may exist. It is after the fact. The issue at hand is instead, given the presence of the landfill, what needs to be done to ensure that it poses no adverse health or environmental risks? The subject risk assessment is one part of the answer to that question. This risk assessment provides additional information that can be used by the community to help ensure that the landfill poses no adverse risks. With the above as a context, we can now examine how each of the four components of the PP applies specifically to the MB HRA.

In addition to these four main components typically considered to comprise the PP, the specific issue of potential chemical contamination of the environment indicates a fifth component. This fifth component has to do with the fact that standards for safe chemical exposure virtually invariably go down (become more stringent) over time not up. This is because as new toxicological data are generated, oftentimes more sensitive endpoints of toxicity are identified. These more sensitive toxicological endpoints then serve as the new, more stringent benchmarks for updating toxic standards such as RfDs. Thus, there is an important limitation in any assessment of chemical risks. Calculation of potential risk can only be made using currently accepted toxicity criteria (e.g. Reference Doses, cancer slope factors) (see listing in Appendix 8.3). These criteria are determined through a process that involves both scientific research (which, at least initially, may be conducted largely by the manufacturers of the substance itself) and a regulatory process that must involve political and economic concerns. The toxicity criteria used in the present HRA are generally accepted today but they are dynamic values that may change over time depending on new toxicity data. Furthermore, they are more likely to change downward rather than upward. Given this characteristic of chemical exposure, the PP instructs us to make conservative recommendations about future use and exposure taking into account the likelihood that toxicity criteria used today may not reflect the most sensitive toxic endpoint.

8.5.1 Exploring Alternatives to the Proposed Action

As mentioned above, this component of the PP does not strictly apply to the MB landfill since the landfill is already in place. However, the MB HRA can be used as a tool to assist in exploring alternatives for addressing any health risks that may be identified by this HRA and guiding any remedial actions.

8.5.2 Placing the Burden of Proof Regarding the Relative Safety of the Proposed Action on the Proponents of the Activity

The MB HRA is consistent with this aspect of the PP. The city of San Diego is responsible for the landfill and they have contracted with SCS to evaluate the health and environmental safety of the landfill site.

8.5.3 Setting and Working Toward Goals that Protect Human Health and the Environment

The MB HRA does not involve setting risk-based standards. However, if it is determined that remediation of the landfill is required many of the risk assessment assumptions and methods used in the MB HRA can be used to develop risk-based remedial objectives.

More generally, the PP also can be used as an alternative way of conceptualizing and identifying goals protective of human health and the environment. For example, by ensuring that such goals take into account the fact that current chemical standards are often limited by an inadequate toxicity database. The more limited the toxicity database for a given chemical the more likely toxicity criteria for the chemical are to be revised downward over time (as discussed above).

8.5.4 Increasing Public Participation and Transparency of the Activity Review Process

Extensive public participation is a core precept of the PP. The establishment of the TAC and its participation in virtually every aspect of the MB HRA is an excellent example of how public participation can be successfully incorporated in public health decision-making, even for a very technical subject such as health risk assessment. The PP also calls for transparency in the public health decision-making process. In other words, all aspects of the decision making should be clear to the public and preferably reproducible by independent parties. The concept of transparency is a hallmark of good risk communication as well. It is addressed in the MB HRA by clearly documenting all the assumptions and methods that went into the risk assessment, presenting those methods and assumptions to public review organizations such as the MB TAC and OEHHHA, and revising those assumptions based on that input. The risk assessment is presented in such a way that anyone could read the document and have all the information necessary to reproduce the risk estimates.

8.5.5 Uncertainty Analysis

There are numerous sources of uncertainty associated with this HRA. The primary sources of uncertainty include the following:

- Uncertainties in the analytical data collected
- Uncertainties in exposure parameter assumptions
- Uncertainties in toxicity criteria
- Uncertainties in fate and transport modeling.

8.5.5.1 *Analytical Data*

Uncertainties regarding the analytical data are related to the simple fact that all soil, soil vapor, groundwater, etc. cannot be sampled and analyzed due to limitations of cost and time. Therefore the risk assessment must rely on a reasonable sample of the various media on which to base the risk estimates. Spatial variation in the contaminant distribution, both laterally and with depth, increases the uncertainty associated with the analytical dataset. Also contributing to analytical uncertainty is the poorly defined nature of the landfill contents. A wide variety of materials have probably been placed in the landfill over the years, the nature and placement of which is in most cases not documented. This leads to considerable spatial variation in the landfill contaminants. Analytical uncertainties may result in both under- or over-estimates of risk depending on whether the actual sampling missed low- or high-concentration areas of the landfill.

8.5.5.2 *Exposure Parameters*

Uncertainties in exposure parameter assumptions are related to the general lack of quantitative studies describing important aspects of human behavior such as incidental soil ingestion rates, length of time spent at one residence, time spent outdoors, etc. In most cases, the values typically used are based on one or a few studies which themselves contain considerable uncertainties (e.g. measurement methods, study population, etc.). In general, this uncertainty has been dealt with by erring on the conservative side and using upper-bound exposure assumptions that will tend to overestimate the exposure occurring to most individuals. This approach to exposure parameter uncertainty is the basis for the RME exposure scenario concept. In summary, uncertainty in the exposure assumptions is most likely to result in an overestimate of health risks.

8.5.5.3 *Toxicity Criteria*

Important uncertainties in toxicity criteria include: 1) the complete absence of RfDs or CSFs for some chemicals, 2) the lack of an adequate toxicological basis for some toxicity criteria, 3) the uncertainty associated with applying oral route toxicity criteria to the dermal or inhalation route, and 4) the complete lack of toxicity criteria for the dermal route, and 5) the dynamic nature of the toxicity database on which toxicity

criteria are based. The general lack of toxicity criteria based on a solid database of underlying toxicological data results in a reduced ability to accurately quantify both non-cancer and cancer risks. This may result in both under- and over-estimation of health risks. A very important uncertainty related to toxicity criteria is that related to the changing nature of toxicity data. New studies regarding the toxicity of chemicals are always being published. However, there is often a considerable lag between the time those studies are published and the time when that new information is reflected in the toxicity criteria. Newer studies in most cases document adverse effects at lower chemical levels than previously established. Yet it may take many months or even years before toxicity criteria are revised to take this new data into account.

8.5.5.4 *Fate and Transport Modeling*

A very important source of uncertainty in the present HRA is the modeling used to evaluate the vapor intrusion exposure pathway (Johnson-Ettinger model) and landfill gas exposure. Exposure and risks associated with these pathways are evaluated using very complex mathematical models that include numerous physical and chemical parameters regarding the expected behavior of soil gases. These parameters have very high degrees of uncertainty associated with them. They are also very dependent on site-specific conditions (e.g. soil type, soil temperature, soil water content) which may or may not be accurately known or characterized, and which may vary greatly across the site. Unfortunately these models (especially the Johnson-Ettinger vapor intrusion model) have been subject to very little field validation. Therefore it is unknown to what extent these model uncertainties result in either under or over-estimation of actual exposure.

8.5.5.5 *Implications of Uncertainties for Decision-Making*

Uncertainties associated with the collected analytical data may be significant and additional samples could be collected to reduce uncertainties regarding site characterization. However, we believe that enough samples were collected to generally be representative of the site conditions. Also, the HRA based all risk estimates on the upper 95 percent upper confidence limit concentration of each contaminant so that it is most likely that the HRA would encompass higher concentrations that may be present in the landfill but not actually measured. The use of the 95 percent upper confidence limit for the assumed exposure concentration would also tend to result in an upper-bound estimate of risks.

Uncertainties described above for exposure parameters have been dealt with in a generally conservative manner throughout the risk assessment. That is, most exposure parameters were selected to err on the side of overestimating risk in this HRA.

Uncertainties associated with toxicity criteria are likely to be much more significant than those associated with the exposure parameters. However, in general the resulting toxicity values also have margins of safety built in. For example, the noncancer RfDs are developed using several safety factors to compensate for intra-

and interspecies extrapolation as well as shorter exposure times. Similarly, the cancer slope factors are calculated using an extrapolation model (the linearized multistage model) that typically results in a higher (more conservative) estimate of cancer risk per unit dose. Other uncertainties associated with development of toxicity criteria include lack of toxicity data (e.g. absence of studies of adequate duration, studies are limited to one species, or inappropriate exposure route, etc.). The effect of all these uncertainties may be significant and at the same time it is impossible to determine whether the net effect would be to increase or decrease risk estimates for any particular chemical.

The uncertainties associated with the vapor intrusion modeling are also likely to be significant. However, at this time the effect of these uncertainties on model predictions has not been characterized. The model used (Johnson-Ettinger model) is the standard and in fact, only, model used for regulatory risk assessments. But whether the model tends to under- or over-estimate indoor air risks related to vapor intrusion is not known at this time. If there were buildings currently at the landfill the model predictions could be checked based on indoor air sampling of those buildings. This could be done if buildings are in fact eventually constructed at the landfill.

8.6 Summary and Conclusions

A baseline HRA was conducted for the MB landfill to evaluate potential health risks of the landfill to the following potentially exposed receptor populations:

- Adult and child recreational user
- Child swimmer
- Commercial worker
- Construction worker
- Homeless or transient adult

The following exposure pathways were evaluated as appropriate depending on the receptor population:

- Incidental soil ingestion
- Dermal contact with soil
- Inhalation of soil particulates in outdoor air
- Inhalation of volatiles in outdoor air
- Inhalation of volatiles in indoor air (vapor intrusion)
- Dermal contact with surface water
- Incidental ingestion of surface water

The HRA was prepared consistent with general risk assessment guidance from the state of California and U.S. EPA. More specific aspects of the risk assessment were reviewed and commented on by OEHHA.

Health risks associated with non-cancer risk, cancer risk, lead exposure, and hazard gases were evaluated.

8.6.1 Non-Cancer Risk

Non-cancer risk was evaluated based on calculation of the HI, with an HI of 1 or less indicating no significant likelihood of adverse non-cancer health effects. HI values exceeded the negligible risk threshold of 1 for the construction worker population only. The HI value for the construction worker population was 4 with deep soil mercury concentrations contributing virtually all of the non-cancer risk. Direct contact with soil through incidental soil ingestion and dermal contact are the primary mechanisms of exposure to mercury.

8.6.2 Lead

Lead risks were evaluated using the Leadsread 7 model approved by California regulatory agencies. Model results indicated that lead does not pose a health risk at the landfill for any of the receptor populations.

8.6.3 Hazard Gases

Risks associated with the hazard gases methane and hydrogen sulfide were also evaluated based on direct measurement of soil gases and for methane, ambient air. Methane concentrations in soil gas generally exceed building standards for safe construction established by the San Diego County Department of Planning and Land Use Building Department. Hydrogen sulfide concentrations in soil gas are below occupational exposure standards and therefore would be expected to be safe in ambient air due to dilution. However, pockets of high concentrations of hydrogen sulfide may be present in the landfill which could pose a hazard to construction workers since hydrogen sulfide is a fast-acting and highly toxic chemical.

8.6.4 Cancer Risk

The highest cumulative cancer risks were for the commercial worker and child recreational user with values of about $2E-05$. By comparison, the negligible cancer risk threshold for California risk assessments is $1E-06$. Cumulative cancer risks for all other receptor populations also exceed the $1E-06$ cancer risk threshold. However, it should be noted that virtually all of this increased cancer risk was due to arsenic present at values generally within the range of naturally occurring background levels. This is true for all other receptor populations as well. The most important exposure pathways contributing to the risk are incidental soil ingestion and dermal contact with soil. Two excessive concentrations of arsenic were detected in soils at 10 ft indicating the presence of some arsenic contamination in deep soils of the landfill. This arsenic primarily poses a risk to construction workers.

9.0 ECOLOGICAL RISK ASSESSMENT

9.1 Introduction

This baseline ecological risk assessment (ERA) evaluates the potential terrestrial ecological risks associated with the MB landfill in San Diego, California. During one of the TAC meetings it was agreed that ecological risks associated with the site would be evaluated in tiers: a terrestrial ERA (Tier 1) and a marine or aquatic ERA (Tier 2). The Tier 2 assessment, which is not part of this ERA, will examine in detail potential effects of landfill contaminants on aquatic life in MB.

The methods used in this ERA were selected first to be consistent with recommendations of the California regulatory agencies primarily responsible for reviewing risk assessments for contaminated sites in California. These agencies include the California DTSC and the California OEHHA. If risk guidance was not available from the California agencies for some aspect of the risk assessment, recommendations of the United States Environmental Protection Agency (U.S. EPA) were used.

Consistent with DTSC ERA guidelines (DTSC, 1996a), a two-phase approach was used to evaluate potential ecological risks associated with the MB landfill. The preliminary phase of the ERA, termed the Scoping Assessment (SA), is a qualitative evaluation of the potential for ecological risks based on a review of the types of habitat, potential ecological receptors, presence of complete exposure pathways, and distribution and degree of contamination. If complete exposure pathways are plausible, the second phase of the risk assessment, termed the Phase I Predictive Assessment (PA), is conducted. Unlike the SA, the PA is a quantitative evaluation of ecological risks that uses contaminant concentration data to calculate chemical exposures to representative or important ecological receptors. These exposure levels are then compared to Toxicity Reference Values (TRVs) to assess risk. When exposure levels are equal to or below the TRV no adverse effects are expected.

This ERA is based on site-specific ecological information contained in the Mission Bay Landfill Site Biological Resources Report (Merkel & Associates, Inc. [MA], 2004).

9.2 Scoping Ecological Assessment

The first step of the SA involved reviewing any previously prepared ecological information about the MB landfill. The only site-specific ecological report available for this site is the Merkel & Associates report (MA, 2004). This report provided the ecological basis for the SA. Following the framework suggested in the DTSC (1996a) guidance, the SA includes:

- A site characterization which consists of a description of the contamination relative to the location and types of habitats and ecological receptor species
- Identification of chemicals of potential ecological concern (COPEC)

- A biological characterization to identify habitats and associated species, ecological receptor species, and the potential presence of special species (Federal and state threatened and endangered species, and California species of special concern)
- An exposure pathway assessment to identify the potential for contact between the ecological receptors and the COPECs

If an SA identifies complete pathways by which ecological receptors may be exposed to COPECs, the assessment progresses to the quantitative PA.

9.2.1 Site Characterization

Detailed descriptions of the contaminant distribution on the site are provided elsewhere in this report.

9.2.2 Data Sources

Data used in this ERA were obtained either from very recent investigations conducted by SCS and described in detail elsewhere in this report, or from a site investigation report prepared by Woodward-Clyde (Woodward-Clyde, 1993). All data from the Woodward-Clyde report were used except for the following:

- Soil VOC data
- Soil vapor survey data
- Groundwater data

The data listed above were considered to be obsolete due to the fact that it is volatile chemical data and therefore would be expected to change significantly over the years since 1993. In the case of the groundwater data, newer data collected by SCS were used instead.

Table 8.1 lists the analytical methods used by SCS to determine chemical contaminants in soils, soil vapor, and groundwater. Virtually all conceivable chemical analyte groups were examined at the MB landfill. The numbers and locations of samples collected from each media are described in detail elsewhere in this report.

9.2.3 Identification of Chemicals of Potential Ecological Concern

“Chemicals of Potential Ecological Concern,” or COPECs, are the subset of chemicals at a site which may potentially present an ecological risk. Frequently at a site, many chemicals are detected, however, the levels of some of these, particularly naturally occurring inorganic chemicals, may be comparable to, or below, natural background concentrations. Such chemicals are typically not of ecological concern and may be excluded from further evaluation. However, the TAC specifically requested that all detected chemicals be included in this ERA to be conservative. This approach is expected to result in an overestimate of ecological risks for the MB

landfill since it includes the risks associated with naturally occurring background levels of inorganic chemicals, particularly arsenic.

9.2.3.1 *Calculation of Exposure Point Concentrations*

Exposure point concentrations (EPCs) are the concentrations of chemical in soil, water, or air that are used to calculate ecological risks. Consistent with U.S. EPA risk assessment guidance (USEPA, 1989), the EPC for a chemical was the lesser of the 95 percent upper confidence limit of the arithmetic mean (95UCLM) or the maximum concentration. For the purposes of the EPC calculation, nondetect values were assigned a value of one-half the sample quantitation limit (SQL), or the practical quantitation limit (PQL) if the SQL was equal to the PQL. These decision rules are consistent with the DTSC guideline document, Use of Soil Concentration Data in Exposure Assessments (DTSC, 1996b).

In addition to the above guidelines, calculation of the soil EPCs requires specifying the depth interval from which soil concentrations are used to calculate the EPCs. For ecological risk evaluation a soil depth interval of 0 to 5 ft. is typically used since this takes into account potential exposures of burrowing animals. This is consistent with a recent DTSC ecorisk guideline note which suggests a depth of 6 ft (DTSC, 1998). A depth of 5 ft was used here based on the practical consideration that soil samples at the site have been collected at 5 ft intervals.

9.2.3.2 *Screening of Chemicals of Potential Ecological Concern*

The initial list of COPECs included all chemicals detected in soil or landfill gas with the exception of chemicals considered an inorganic essential nutrient (e.g., potassium, calcium, and magnesium). Table 9.1 shows the initial list of COPECs in soil and landfill gas and corresponding EPCs.

9.2.3.3 *Screening of COPECs Against Ecotoxicological Benchmarks*

The next step in identifying the final COPECs for the MB landfill ERA involved comparing the EPCs to ecotoxicological screening benchmarks (ESB). ESBs are levels of chemicals in soil or water, below which no adverse effects to wildlife are expected to occur. ESBs selected for comparison were the most conservative reported in the published literature and, when available, include protection of plants. Any COPEC which had an EPC less than or equal to the corresponding ESB was excluded as a final COPEC. A comparison of the soil EPCs to ESBs is shown in Table 9.2. Note that there are no ESBs for landfill gas so landfill gas COPECs were not screened against ESBs. The final list of COPECs (soil and landfill gas) is shown in Table 9.3.

9.2.4 Biological Characterization

The purpose of the biological characterization is to determine the types and extent of various habitats in the vicinity of a site, as well as identify the associated wildlife species inhabiting or visiting these areas. Threatened, endangered, sensitive and special species were also identified or confirmed as part of the biological characterization. As noted above, the biological characterization was developed based on information contained in MA (2004).

9.2.4.1 Identification and Classification of Habitats

Ecological habitats were identified and classified by MA (2004). The MA report identified a total of eight habitats at the subject site. However, one of these was “urban/developed” habitat comprising about 23% of the site area. Since this “habitat” refers to strictly urban areas there is no potential for ecological value; therefore this habitat was not considered further. Four habitats make up virtually all of the remaining 75% of the site. These include:

- Disturbed Habitat (36.4%)
- Non-native Vegetation (21.8%)
- Southern Foredunes (8.8%)
- Coastal Sage Scrub (7.3%)

Because of the small area of the site and the limited diversity of fauna, a single ERA conceptual site model was developed consisting of a composite of these four habitats. The characteristics of these four habitats are described below.

Disturbed Habitat.

Disturbed habitat at the MB landfill is area used as access paths for vehicles and pedestrians and typically consists of bare ground or very limited ground cover (less than 30 percent). Flora found in these areas consists primarily of the non-native ruderal species Russian thistle (*Salsola tragus*) and Australian saltbush (*Atriplex semibaccata*).

Non-Native Vegetation.

This habitat (Oberbauer Code 11000) comprises landscaped areas of the landfill and includes both exotic and native drought tolerant species. Native species include Torrey pine (*Pinus torreyana*) and lemonadeberry (*Rhus integrifolia*). Non-native species consist of purple rock-rose (*Cistus incanus*), Perez rosemary (*Limonium perezii*), pride of Madeira (*Echium fastuosum*), Brazilian pepper tree (*Schinus terebinthifolius*), Sydney wattle (*Acacia longifolia*), Mexican palo verde (*Parkinsonia aculeata*), and ngaio (*Myoporum laetum*).

Southern Foredunes.

The southern foredunes habitat (Oberbauer Code 21230) is located primarily in the eastern portion of the landfill site. Predominant species include California sun cup (*Camissonia bistorta*), beach evening primrose (*Camissonia cheiranthifolia*), spiny threecornerjack (*Emex spinosa*) and sea-rocket (*Cakile maritima*). Two sensitive plant species, Nuttall's lotus and coast woolly-heads are present in this habitat.

Coastal Sage Scrub.

This habitat (Oberbauer Code 32000) is found throughout the MB landfill site. It consists primarily of drought deciduous shrubs ranging from 2 to 4 feet high. Predominant species include California sagebrush (*Artemisia californica*), coyote brush (*Baccharis pilularis*), broom baccharis (*Baccharis sarothroides*), and flat-top buckwheat (*Eriogonum fasciculatum*).

9.2.4.2 *Site Inventory of Plant and Animal Species*

The most common plants and animals associated with each habitat type are shown in Table 9.4. In addition, a complete list of all animals and plants that may be present at the MB landfill, based on habitat type and geographic range, is provided in Table 9.5 (animals) and Table 9.6 (plants). The list in these tables includes all species either directly observed at the MB landfill by field biologists from MA or which may potentially be present because the MB landfill is within the geographical range of the species, and the habitat is consistent with the ecological requirements of that species.

9.2.4.3 *Identification of Threatened, Endangered, Sensitive and Special Species*

Review of existing reports and data indicate that no rare, threatened, or endangered species were observed onsite during site surveys conducted by field biologists of Merkel & Associates, Inc. Although no threatened or endangered species have been observed in the area, there is potential for utilization of the MB landfill by some sensitive or special species based on the habitat types available at the site and geographical range information. A species is most commonly defined as a "sensitive species" if it has a limited area of occurrence. Other considerations in listing a species as sensitive include specialized habitat preferences or special sensitivity to habitat disturbance. A special species is a plant or animal listed on the CDFG special plant or animal list (CDFG, 2004 and 2005a). Listing as a special species may occur for a number of reasons (e.g. the plant or animal is rare, it is currently listed or proposed for listing under the state or federal endangered species acts, or is endangered due to loss of habitat). Endangered and threatened species were identified based on MA (2004) and CDFG (2005b,c). Endangered, threatened, sensitive, and special plant and animal species that may potentially use the MB landfill are listed in Table 9.7.

9.2.5 Selection of Representative Ecological Receptors

Because it is not possible to assess the effects of the COPECs on every potentially exposed species, key species that are representative of major trophic and/or taxonomic groups for each distinct habitat type are selected for the ERA. The DTSC (1996a) guidance provides the following criteria which were used to select representative ecological receptor species:

- Occurs on the site
- Occupies a high trophic level (i.e., top predator) or is important as a prey species
- Has a high potential for chemical exposure
- Supporting toxicity data is available
- The species has a documented sensitivity to COPECs
- The species has protected status
- The species is economically important
- The species has high societal, recreational, or commercial importance.

Based on consideration of the above criteria, ecological receptor species for the Mission Bay landfill habitats were selected. These receptor species include: the California ground squirrel (*Spermophilus beecheyi*), the northern harrier (*Circus cyaneus*), the killdeer (*Charadrius vociferous*), and the mourning dove (*Zenaida macroura*).

The California ground squirrel was selected for the following reasons:

- It has been observed on the Site.
- It is an important prey item for carnivores on the Site.
- It is a burrowing animal and therefore can represent chemical exposure via soil gas.
- Physiological parameters needed to estimate food and soil ingestion are readily available for rodents.
- Toxicity data is readily available for small rodents.
- It represents entirely herbivorous species.

The northern harrier was selected as a representative ecological receptor because:

- It has been observed on the Site.
- It is the only carnivore that has been observed on the Site.
- It is a “sensitive” species.

The mourning dove was selected as a representative ecological receptor based on the following criteria:

- It has been observed on the Site.
- It is representative of exposure for primarily herbivorous birds.

- It is primarily a ground-dwelling bird and therefore would represent an upper-bound chemical exposure for birds.

The killdeer was selected as a representative ecological receptor because:

- It has been observed on the Site.
- It is representative of exposures for primarily insectivorous birds.
- It is primarily a ground-dwelling bird and therefore would represent an upper-bound chemical exposure for birds.

The rationale used for selection of these receptors is summarized in Table 9.8. Exposure and effects were assessed for these receptor species as indicators of the potential for adverse effects at the population level and the ecosystem as a whole.

9.2.6 Identification of Complete Exposure Pathways

A complete exposure pathway is an exposure pathway in which there is considered to be some real possibility for significant contact between the contamination source and the ecological receptor. Chemical contamination at the MB landfill resides in the soil and groundwater. However, terrestrial ecological receptors will only be exposed directly to soil. Therefore, only soil-related exposure pathways are relevant for this ERA. The most important soil exposure pathway is direct soil ingestion. In addition, exposure via ingestion of contaminated plants (herbivores) and prey species (carnivores, insectivores) may also be significant; therefore these pathways were also quantitatively evaluated. Finally, burrowing animals may be exposed to soil gas. The latter pathway was evaluated for the ground squirrel.

9.2.7 Conceptual Site Model

Based on the exposure pathways and ecological receptors described above, a conceptual site model was developed to represent a composite of the entire site. This model (Figure 9.1) relates chemical sources, release mechanisms, affected media, exposure routes, ecological receptors, and potentially complete pathways.

9.2.8 Scoping Assessment Conclusions

Based on the presence of the COPECs identified above (Table 9.1), and the potentially complete exposure pathways indicated in the conceptual site model (Figure 9.1), a quantitative Phase I PA was developed.

9.3 Phase I Predictive Assessment

In contrast to the SA, which is a qualitative evaluation of ecological risks, the objective of the PA is to quantify the ecological risks associated with potential exposures to COPECs.

To accomplish this, the PA compares estimated exposures for each COPEC to the corresponding TRV derived or obtained from the ecotoxicological literature. TRVs are chronic exposure levels, below which, adverse ecological effects are not expected. If the estimated exposure levels exceed the TRV, then there is some potential for adverse ecological effects.

9.3.1 Exposure Assessment

The purpose of the ecological exposure assessment is to quantify chemical exposure to representative ecological receptors. The ecological exposure assessment consists of the following steps:

- Calculating exposure point concentrations of chemicals in environmental media
- Identifying the COPECs
- Identifying representative ecological receptors
- Identifying complete exposure pathways
- Calculating exposure levels for each receptor for each complete exposure pathway.

The first four steps of this process were completed as part of the SA. The remaining step, calculation of exposure levels, is the focus of the following section.

9.3.1.1 Calculation of Ecological Receptor Chemical Intakes

To estimate exposure to COPECs, a wildlife ingestion model was used, along with the EPCs, to determine the long-term average daily exposure or Chronic Daily Intake (CDI) of COPECs. This model accounts for receptor characteristics that influence exposure such as habitat preferences, home ranges, migratory behavior, and diet. The model incorporate species-specific exposure parameters, including body weight, ingestion rate, and fraction of diet composed of vegetation or prey, and incidental soil ingestion from the affected area (Table 9.9). The equation below shows the general form of the model that was used to calculate the CDI, as adapted from the Wildlife Exposure Factors Handbook (USEPA, 1993):

$$CDI = \frac{((IRP \times CP) + (IRV \times CV) + (IRS \times CS)) \times AUF}{BW}$$

where:

CDI	=	Chronic Daily Intake from all completed exposure pathways (mg/kg body weight/day)
IRP	=	ingestion rate of prey (kg/day)
CP	=	concentration of contaminant in prey (mg/kg)
IRV	=	ingestion rate of vegetation (kg/day)
CV	=	concentration of contaminant in vegetation (mg/kg)

IRS	=	ingestion rate of incidentally-ingested soil (kg/day)
CS	=	concentration of contaminant in soil (mg/kg)
BW	=	body weight of ecological receptor (kg)
AUF	=	area use factor (unitless)

The AUF is the fraction of time the animal spends in the contaminated area and was calculated as the size of the MB landfill site (148 acres not including the urban or developed portion) divided by each species' home range, with a maximum value of 1 or 100 percent.

The concentrations of inorganic COPECs in vegetation, CV, were calculated using the plant uptake factors of Baes et al. (1984) for the vegetative portion of plants as follows:

$$CV = B_v \times CS$$

where Bv is the Baes plant uptake factor for inorganic chemicals into the vegetative portion of plants. Since the Baes plant uptake factors were developed on a dry weight basis they were first converted to a wet or fresh weight basis by multiplying by a factor of 0.125 (the ratio of the moisture content of soil over the average moisture content of plants) before use in the above equation. The plant uptake factors for each inorganic COPEC are shown in Appendix 9.3, Table 9.3.1. Uptake of organic COPECs by plants was considered to be negligible (TTEMI, 2000; CRSI, 2003).

For the ecological receptors that consume prey (northern harrier), an uptake factor of 0.074 was used to convert the soil concentration of inorganic COPECs to a small mammal prey concentration. The value of 0.074 is the average uptake of 13 inorganic chemicals from soil by small prey animals (Sample et al., 1998a). For the killdeer, the concentration of inorganic COPECs in prey (invertebrates) was assumed to be equal to the soil concentration (Sample et al., 1998b). Concentrations of organic COPECs in small mammals and insects were assumed to be negligible due to the very low concentrations of organic COPECs in soil and metabolic elimination.

Finally, for the ground squirrel, a fossorial or burrowing animal, exposure to landfill gas was added to calculated exposures from plant and soil ingestion. Landfill gas uptake was calculated as follows:

$$CDI_{lg} = \frac{CLG \times CF_{lg} \times InhR \times AUF}{BW}$$

Where:

CDI _{lg}	=	Chronic Daily Intake from the soil gas exposure pathway (mg/kg body weight/day)
CLG	=	Concentration in landfill gas (µg/m ³)

CFlg = Conversion factor for landfill gas (1 mg/1000 µg)
InhR = Inhalation rate (m³/day)
BW = Body weight (kg)

An inhalation rate for the California ground squirrel of 0.27 m³/day was assumed (Carlsen, 1996).

9.3.2 Ecological Risk Characterization

The ecological risk characterization portion of an ERA quantifies the potential for an adverse ecological effect by comparing the CDI for an ecological receptor to a corresponding TRV. As indicated above, the TRV is a level of exposure below which no adverse effect to the ecological receptor is expected. Before an appropriate TRV can be selected for comparison to the CDI, however, a decision must be made regarding what qualities of the ecological receptor should be protected as a result of the ecological risk assessment. These qualities are referred to as assessment endpoints.

9.3.2.1 *Selection of Assessment Endpoints for Representative Species*

Assessment endpoints are the qualities of the ecosystem which are desired to be protected and preserved. Measurement endpoints are the measurable criterion by which it is determined that the assessment endpoint has or has not been attained. The proposed assessment endpoints associated with the representative ecological receptor species identified above are summarized in Table 9.8. Assessment endpoints shown in Table 9.8 can be generalized as the protection and preservation of populations of representative receptors. Due to the difficulties in measuring impacts to entire wildlife populations, the measurement endpoints used focus on adverse health effects that can be measured at the individual level (e.g. increased mortality, impaired reproductive capability, organ system impairment).

9.3.2.2 *Derivation of Toxicity Reference Values*

TRVs for each COPEC were selected from benchmark reports (e.g. Sample et al., 1996) for mammalian and avian receptors, or from the published scientific literature, if available. TRVs are summarized in Table 9.10. TRVs were not available for several of the landfill gas COPECs. TRVs were selected that are relevant to the assessment endpoints and are appropriately conservative. For these reasons, TRVs were preferentially based on toxicity studies that:

- Assess chronic exposures
- Evaluate dietary exposures or oral ingestion routes, and
- Measure reproductive endpoints.

Depending on data quality and availability, the highest no-observed-adverse-effect level (NOAEL) was generally selected as the basis for the TRV. Consistent with recent DTSC guidelines (DTSC, 1999), TRVs for the test or experimental species were not scaled allometrically for body weight differences when the difference between the test species and ecological receptor body weight was less than twofold. When body weights differed by more than twofold the following scaling equation was used to adjust the TRV for mammals (Sample and Arenal, 1999):

$$TRV_w = TRV_t \left(\frac{BW_t}{BW_w} \right)^{0.06}$$

where:

TRV _w	=	Toxicity Reference Value for the wildlife species
TRV _t	=	Toxicity Reference Value for the test species
BW _w	=	body weight of the wildlife species
BW _t	=	body weight of the test species

For birds, a scaling exponent of -2 was used instead of 0.06 in the equation above (Sample and Arenal, 1999). It should be noted that these scaling exponents are derived based on acute toxicity data and may not necessarily be appropriate for the extrapolation of chronic data.

9.3.2.3 Hazard Quotient and Hazard Index Calculations

The potential for ecological risks was quantified by comparing the exposure estimates (CDIs) to the TRVs, resulting in a Hazard Quotient (HQ) in a manner analogous to that for human health risk assessment:

$$HQ = \frac{CDI}{TRV}$$

If, for a given receptor and COPEC, the CDI does not exceed its TRV (i.e., HQs are less than 1), adverse effects are not expected.

It is possible for the HQ for each COPEC at a site and to be less than 1 but still present a potential for adverse ecological effects. This can happen from the cumulative effects of contaminants that have a similar toxic mechanism and/or target organ. Although each contaminant exposure level may be acceptable when considered separately, the total cumulative effect of similarly acting toxicants can create a potential for an adverse effect. To ensure that the cumulative ecological risk from multiple similarly acting contaminants is adequately considered, the total HQs across all contaminants are summed to obtain a Hazard Index (HI). This is a conservative first step in the analysis of cumulative effect potential because it disregards the specific mechanism of toxicity or target organ.

Table 9.11 shows that HQ values for all ecological receptor species and COPECs were less than one. The total HI for each ecological receptor is also less than 1, indicating no significant likelihood of adverse ecological effects.

9.4 *Uncertainty Analysis*

The accuracy of any ecological risk assessment is often limited by the lack of scientific data. This lack of data can be expected to result in considerable uncertainty in the final quantitative risk estimates. The greatest sources of uncertainty associated with the present ERA are likely to be due to the following factors: inaccuracies in the estimates of inorganic COPEC uptake by plants and uncertainty in the relationship between soil and plant concentrations and tissue concentrations in prey animals. There is also considerable uncertainty associated with soil ingestion rate exposure parameter. Since the soil ingestion pathway is typically the most important exposure pathway, this uncertainty may lead to significant under- or over-estimation of ecological risks.

Another important source of uncertainty is the lack of ecological receptor-specific toxicity data for several site-related chemicals. Specifically, TRVs were not available for several of the landfill gas COPECs. This will result in a slight underestimation of risks for burrowing species.

The lack of specific toxicity data for most wildlife ecological receptors is another major source of uncertainty. In most cases, toxicity data for mammals is available only for laboratory animals (rats, mice) typically used for toxicity testing. Avian toxicity data may only be available for the chicken or duck. Wildlife species may have lesser or greater sensitivity to chemicals than laboratory test species resulting in either under- or overestimates of ecological risk.

9.5 *Summary and Conclusions*

A baseline ERA, focusing on terrestrial ecological receptors, was conducted for the Mission Bay landfill. The ERA was conducted in coordination with the Mission Bay landfill TAC and prepared consistent with state of California guidance for ERAs at hazardous waste sites. Risks to the following representative ecological receptors were evaluated:

- Northern harrier
- California ground squirrel
- Mourning dove
- Killdeer.

Exposures via the following pathways were evaluated:

- Soil ingestion (all receptors)
- Prey ingestion (harrier, killdeer)
- Plant ingestion (ground squirrel, mourning dove)

- Landfill gas inhalation (ground squirrel only).

The total HI for each ecological receptor was less than 1, indicating no significant likelihood of adverse ecological effects.

10.0 CONCLUSIONS

As described in Section 1.4, the scope of services for this assessment was described in the RFP. The seven points are listed again here with the appropriate report sections in which the response to them is described.

1. Determine the horizontal and vertical extent of the Mission Bay Landfill to determine where COPC [Contaminant of Potential Concern] may have been disposed of (Sections 3, 5, 6, and 7).
2. Determine/identify the average and maximum concentrations of any chemical contaminants and distribution within the boundaries of the Mission Bay Landfill to determine COPC (Sections 5 and 8).
3. Compile and compare previous analytical results to ensure that all COPC are included in any health risk assessment (Sections 4.2, 4.3, and 8.3).
4. Determine the fate and transport of COPC that may have been disposed of during the active life of the Mission Bay Landfill (Sections 6 and 7).
5. Determine any potential ecologic or human health impact(s) of the COPC by exposure to the soil, sediments, groundwater, surrounding surface water, or air (Sections 8 and 9).
6. Evaluate any potential ecological or human health impacts(s) to determine if remediation is warranted (Sections 8 and 9).
7. Present potential alternative methods if remediation is warranted (Sections 10 and 11).

In addition, as requested by the TAC during discussion of the submitted draft Workplan, the Precautionary Principle was applied to the Site assessment as described in Section 8. A brief summary of the main conclusions listed in the previous sections follows:

10.1 Physical Extent

The vertical extent of the landfill has been defined during this assessment, and the delineation of the horizontal extent has been refined. Figure 6.1 depicts the lateral limits of the landfill; Figures 6.1 and 6.2 depict the thickness of the landfill and cover soils. The landfill area is estimated to be 113 acres, and the landfill volume is estimated from the isopach map to be 786,600 cubic yards. The average landfill thickness is 11.3 feet, and ranges from 0.5 to 22.5 feet.

10.2 Chemical Composition

A list of COPCs has been collated for each of the media at the landfill including soils, landfill gas, soil vapors, and groundwater. New COPCs have been identified as presented in Table 5.5. A summary of the COPCs analyzed in each medium, and the maximum concentrations reported by the analytical laboratories is included as Table 5.25. Statistics describing the average and maximum concentrations of all COPCs are summarized in Appendix 8.2.

10.3 Landfill Cover

The landfill is covered by 1.5 to 19.5 feet of soil. Approximately 31% of the cover is comprised of asphaltic concrete paving and hardscape. Soil testing has been conducted and the surficial soils do not have COPCs at significant concentrations.

Current landfill regulations (CCR Title 27), as they pertain to closure of active landfills, require a cover system four-feet thick, comprised of (bottom to top) a two-foot “foundation layer”, a one-foot barrier layer with permeability no greater than 10^{-6} cm/sec, and a one-foot “vegetative” layer. This is referred to as the “prescriptive” cover. Many landfills have been allowed to be covered with a 5-foot or deeper “monocover,” that can be shown to provide equivalent performance to the prescriptive cover. These requirements are not necessarily applicable to Mission Bay Landfill. In general, the RWQCB and LEA will set requirements for covers on older (pre-1984) landfills based on conditions at the site, when and if the site comes under their scrutiny. (Note: there are hundreds of old landfills in California that have never been evaluated relative to, much less upgraded to, modern closure standards. They are addressed by the various regulatory agencies if and when problems arise, and/or redevelopment is proposed.) The Mission Bay Landfill cover does not meet these requirements. The thickness of the cover is less than four feet in some areas, and in other areas it is unlikely, based on visual observation, that it would meet an equivalent-performance test, as it appears relatively permeable. However, given the age of the site, the relatively low levels of COPCs in groundwater, the fact that the groundwater is not potable, and the lack of evidence of hazardous gas emissions (see below), the RWQCB would not be expected to require any cover upgrades.

Arsenic in soil, a naturally occurring element, is the main risk driver for the Site. However, all surface and shallow soil concentrations (less than 10 feet bgs) of arsenic at the Mission Bay Landfill were less than 10 mg/kg, below the DTSC arsenic background guideline of 11.3 mg/kg. The maximum soil concentration of arsenic detected was 60 mg/kg and another soil sample had a concentration of 45 mg/kg. However, both of these samples were detected at 10 feet bgs. Because of the depth of these samples they pose a potential risk only to construction workers. Construction on the site is unlikely due to the high concentrations of methane present in landfill gas and the problems posed by likely continued settlement of the landfill surface (see below).

10.4 Landfill Gas

Methane occurs within the landfill at concentrations ranging up to 57% (by volume), with an average concentration of about 20%. Although the methane generation rate will continue to decline as the site ages, it may not decline to negligible amounts for many years to come. The raw landfill gas (LFG) also contains some COPCs; benzene and vinyl chloride were detected. This is not unexpected – LFG at virtually all municipal landfills, regardless of whether they received systematic amounts of hazardous substances, contains low concentrations of benzene and vinyl chloride. However, sampling of air above the landfill (integrated surface and ambient air sampling) did not result in the detection of any COPCs above background.

The continued generation of methane could pose a hazard if it can migrate laterally toward existing or future buildings on or near the Site. If it were allowed to accumulate in a building space it could pose an explosive hazard. It is conventionally believed that methane can migrate up to 1,000 feet from the landfill boundary; however given the age and relatively shallow depth of Mission Bay Landfill, it is extremely unlikely that methane would migrate that far. (Note that regulators have never required the Site to have a perimeter monitoring system, suggesting that they realize the prospect of hazardous migration is low.) It appears that the only area of the Site perimeter at which methane may pose a migration hazard is along the west and northwest boundary. We recommend that methane migration monitoring probes be placed in this area.

With respect to surface emissions, the combination of the low generation rate, the low quantities of COPCs in the raw gas, and the presence of the soil cover result in no significant emissions. Neither the surface sampling nor the APCD's ambient air testing revealed any significant concentrations of COPCs. There appears to be no significant human health risk and therefore no need for any type of gas control system at the Site. We recommend that periodic surface emissions monitoring continue, along the lines of the program required under APCD Rule 59; if the benign results of testing do not change over the period of a year, the monitoring could probably be safely terminated.

Most importantly, existing concentrations of methane in the landfill gas do significantly exceed San Diego County's acceptable limits for safe construction. In addition, hydrogen sulfide concentrations in landfill gas may pose a risk to construction workers. In addition, there are a few utility trenches within the landfill boundaries. Utility trench bedding/backfill can be a conduit for gas migration, if it passes through or within the gas "plume" of the landfill. Such trenches can be fitted with a "dam", a bentonite plug at the location where the trench leaves the methane zone. Drawings of the Site and surrounding area showing the distribution of underground utilities were obtained from the City of San Diego. With the exception of the area along Sea World Drive and the restrooms near the boat basin, there are few utilities within the South Shores area. Because much of Sea World Drive is located directly above known areas of waste disposal, it is possible that the utility trenches could serve as preferential pathways for the migration of vapors and groundwater from the buried waste. No information was reviewed concerning the depth of the utility trenches or the possibility that buried waste was disturbed during their excavation. The LEA requires that maintenance workers perform tests for methane in utility vaults on landfills in order to protect their health and safety.

Buildings have been constructed safely atop landfills, and structures could be constructed on Mission Bay Landfill. However, buildings would have to be designed to prevent methane infiltration, which would pose an explosive hazard, and to prevent hydrogen sulfide infiltration, which is an odor nuisance at low levels and toxic at higher levels. Buildings would also have to accommodate future differential settlement.

Protection from subsurface gas infiltration (for either methane or hydrogen sulfide) is conventionally accomplished through the placement of a gas-impermeable membrane under

the building, typically combined with passive or active (mechanical) venting of subsurface gas, and often with gas sensors/alarms within the structure.

Differential settlement can be expected as the organics within the refuse continue to decompose. Although the landfill is not very deep, and decomposition/settlement rates are well past peak, settlement cannot be ignored. Mitigation of differential settlement can be accomplished by constructing buildings on drilled or driven pile foundations, or through the construction of lightweight structures with adjustable foundations. However, the possible presence of drums that still may contain hazardous materials could pose a safety hazard during construction of foundation piles—this may further preclude construction of buildings on the Site.

Both methane protection and enhanced foundations for settlement add considerably to the cost of conventional construction.

10.5 Groundwater Characterization

The hydraulic gradient is generally from the river to the bay, and groundwater is subject to tidal influences. There is a zone of groundwater approximately 2 to 8 feet thick with total dissolved solids (TDS) concentrations of 15,000 (river channel waters) to 35,000 mg/L (bay/ocean water) interpreted to overly a zone of fairly stagnant, hypersaline groundwater of over 40,000 mg/L TDS. Mixing and tidal influences are evident within the upper zone. There is a shorter path for groundwater across the landfill towards the boat basin, and the gradient is slightly higher across this area.

From the results of groundwater sampling in monitoring wells and soil borings, there appears to be very little in the way of VOCs or SVOCs discharging from the landfill into the bay. The landfill cover is largely permeable and portions of the Site are irrigated; however, no substantial decreases in groundwater salinities were observed related to irrigation or stormwater infiltration.

10.6 Solvents, Thallium, and Chromic Wastes

Review of historical documentation indicates that the most potentially problematic wastes placed in the landfill are chlorinated solvents and chromium. There is no evidence of highly elevated concentrations of chlorinated solvents such as TCE or PCE remaining in the landfill. Overall the analytical data show that either significant degradation of HVOCs has occurred, or significant quantities of PCE and TCE were not put in the landfill. Historical documentation indicates that significant quantities of wastes were placed in the landfill approximately 50 years ago, however the majority of these wastes do not appear to have been solvents. Given the relative ratios of degradation products, the highly reducing (anaerobic, methanogenic) geochemical environment, and the duration of time, it is likely that the solvents that were present have undergone an extensive and advanced process of degradation.

Historical waste disposal practices included placing waste solvents in metal drums. While the drums would be expected to corrode in the saline subsurface environment, there is a potential for future releases to occur from sealed drums should they remain intact after 50 years. Continued groundwater monitoring of the Site is anticipated and should be capable of detecting a release of pure phase solvents should a release occur.

For a number of years, concerns have been voiced about the presence and concentrations of thallium in the landfill. As a result of these concerns Chuck Budinger, a former member of the TAC, researched the issue and concluded that certain analytical methods using light spectrometry can cause interference by other metals and lead to erroneous results, both for Thallium or the other metals.

Our review of previous thallium data in surface water, groundwater and sediment samples revealed a clear pattern of concentrations of thallium that were consistent within a sampling event, but not between sampling events, during the mid 1980's and again in 1996. It is our interpretation that the most likely explanation of these patterns is that they represent the type of interference described by Mr. Budinger. The interference may occur due to the close proximity of the thallium peak to those of other (more common) elements with higher concentrations. This has the effect of raising the base level of the spectrum, which may lead to misinterpretation of concentrations for the metal with the lower concentration (e.g. thallium). Laboratory results for thallium in the current study showed no detectable concentrations of thallium in samples of surface or subsurface soils or sediment, and a maximum concentration of thallium in groundwater that is lower than the public health goal.

Further, hexavalent chromium is not chemically stable under the geochemical conditions found in the landfill, which explains why it was not reported in groundwater samples, and was detected at very low concentrations in a few of the soil samples analyzed.

10.7 Human Health Risk Assessment

A baseline HRA was conducted for the Mission Bay Landfill to evaluate potential health risks of the landfill to the following potentially exposed receptor populations:

- Adult and child recreational user
- Child swimmer
- Commercial worker
- Construction worker
- Homeless or transient adult.

The following exposure pathways were evaluated as appropriate depending on the receptor population:

- Incidental soil ingestion
- Dermal contact with soil
- Inhalation of soil particulates in outdoor air
- Inhalation of volatiles in outdoor air

- Inhalation of volatiles in indoor air (vapor intrusion)
- Dermal contact with surface water
- Incidental ingestion of surface water.

The HRA was prepared consistent with general risk assessment guidance from the state of California and U.S. EPA. More specific aspects of the risk assessment were reviewed and commented on by OEHHA. Health risks associated with non-cancer risk, cancer risk, lead exposure, and hazard gases were evaluated.

10.7.1 Non-Cancer Risk

Non-cancer risk was evaluated based on calculation of the Hazard Index (HI), with an HI of 1 or less indicating no significant likelihood of adverse non-cancer health effects. HI values exceeded the negligible risk threshold of 1 for the construction worker population only. The HI value for the construction worker population was 4 with deep soil mercury concentrations contributing virtually all of the non-cancer risk. Direct contact with soil through incidental soil ingestion and dermal contact are the primary mechanisms of exposure to mercury. It should be noted that future construction on the site may be considered unlikely due to high concentrations of methane in landfill gas and continued differential settlement. However, construction is possible on landfills and, if it is proposed, then a health and safety plan should be developed to address appropriate levels of worker protection.

10.7.2 Lead

Lead risks were evaluated using the Leadsread 7 model approved by California regulatory agencies. Model results indicated that lead does not pose a health risk at the landfill for any of the receptor populations.

10.7.3 Hazard Gases

Risks associated with the hazard gases methane and hydrogen sulfide were also evaluated based on direct measurement of soil gases, and for methane, ambient air. Methane concentrations in soil gas generally exceed building standards for safe construction established by the San Diego County Department of Planning and Land Use Building Department. Hydrogen sulfide concentrations in soil gas are below occupational exposure standards and therefore would be expected to be safe in ambient air due to dilution. However, pockets of high concentrations of hydrogen sulfide may be present in the landfill which could pose a hazard to construction workers since hydrogen sulfide is a fast-acting and highly toxic chemical.

10.7.4 Cancer Risk

The highest cumulative cancer risks were for the commercial worker and child recreational user with values of about 2E-05. By comparison, the negligible cancer risk threshold for California risk assessments is 1E-06. Cumulative cancer risks for all

other receptor populations also exceed the 1E-06 cancer risk threshold. However, it should be noted that virtually all of this increased cancer risk was due to arsenic present at values generally within the range of naturally occurring background levels. This is true for all other receptor populations as well. The most important exposure pathways contributing to the risk are incidental soil ingestion and dermal contact with soil. Two excessive concentrations of arsenic were detected in soils at 10 feet, indicating the presence of some arsenic contamination in deep soils of the landfill. This arsenic primarily poses a risk to construction workers if excavation were to be conducted by unprotected workers at these locations. However, as noted above, future construction at the landfill is unlikely due to high concentrations of methane in landfill gas and potential settlement.

10.8 Ecological Risk Assessment (ERA)

A baseline ERA, focusing on terrestrial ecological receptors, was conducted for the Mission Bay Landfill. The ERA was conducted in coordination with the Mission Bay Landfill TAC and prepared consistent with state of California guidance for ERAs at hazardous waste sites. Risks to the following representative ecological receptors were evaluated:

- Northern harrier
- California ground squirrel
- Mourning dove
- Killdeer.

Exposures via the following pathways were evaluated:

- Soil ingestion (all receptors)
- Prey ingestion (harrier, killdeer)
- Plant ingestion (ground squirrel, mourning dove)
- Landfill gas inhalation (ground squirrel only).

The total HI for each ecological receptor was less than 1, indicating no significant likelihood of adverse terrestrial ecological effects. It is expected that potential landfill effects on aquatic wildlife will be addressed via an aquatic or marine ecological risk assessment separate from the current scope of work.

11.0 RECOMMENDATIONS

Potential remediation options are proposed for the Site based on:

1. The elevated concentrations of methane in the landfill gas
2. The relatively thin soil cover in the eastern part of the landfill and,
3. The potential for COPCs at low concentrations to affect aquatic life in Mission Bay and the San Diego River.

Our recommendations for the Site are as follows:

- Expand the existing methane monitoring system at the landfill in collaboration with the LEA. At a minimum this monitoring system should consist of standard landfill gas monitoring wells on the west and northwest perimeters of the landfill in the vicinity of Sea World and the proposed Mission Bay Boat and Ski Club; as well as monitoring of utility vaults at the landfill. (It is our understanding that at least two landfill gas probes were installed by Sea World, and that monitoring of utility vaults prior to access is required by the LEA.)
- Any future construction in the landfill would have to take into account the continued presence of methane and hydrogen sulfide, as well as differential settlement. Because landfill gas concentrations of methane significantly exceed the San Diego County Department of Planning and Land Use Building Department limit (10% of the lower explosive limit), at a minimum methane mitigation (membrane, vents, sensors) would be required.
- Place additional soil cover in the eastern part of the landfill (35-acre parcel) to create an effective physical barrier. The cover is thinner in this area than in any other part of the landfill and, in places could easily be breached by animals digging or burrowing or by individuals attempting to scavenge metallic debris. The type of soils and vegetation used for the additional cover should be chosen to be compatible with or enhance the existing biological habitat.
- After cover enhancements are complete, perform regular monthly surface emissions testing (integrated surface sampling) for one year to confirm results of this Assessment through four seasons.
- Conduct a Tier 2 marine or aquatic ecological risk assessment to examine in detail potential effects of landfill contaminants on aquatic life in Mission Bay.
- Continue the groundwater monitoring program as stipulated in the RWQCB Order. Reset the intake depths of the pumps in the existing monitoring well network so that the shallow "active" groundwater zone is sampled and conduct sampling using low-flow sampling methodologies. The analytical program may need to be modified depending on the results of the Tier 2 ERA.

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13.0 ACRONYMS AND ABBREVIATIONS

SECTION 8

atm-m ³ /mol	Atmospheres-m ³ /mole
CDI	Chronic Daily Intake
COPC	Chemicals of Potential Concern
CSF	Cancer Slope Factor
dL	Deciliter
DTSC	Department of Toxic Substances Control
EPC	Exposure Point Concentration
g	Gram
HRA	Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
JE	Johnson-Ettinger
MDL	Method Detection Limit
mol	Moles
OEHHA	Office of Environmental Health Hazard Assessment
PP	Precautionary Principle
PQL	Practical Quantitation Limit
QA	Quality Assurance
QC	Quality Control
RA	Risk Assessment
REL	Chronic Reference Exposure Level
RfD	Reference Dose
RME	Reasonable Maximum Exposure
SQL	Sample Quantitation Limit
SVOC	Semivolatile Organic Compound
TAC	Mission Bay Technical Advisory Committee
TPH	Total Petroleum Hydrocarbons
UCLM	Upper Confidence Limit of the Mean
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

SECTION 9

CDFG	California Department of Fish and Game
CDI	Chronic Daily Intake
COPEC	Chemicals of Potential Ecological Concern
DTSC	Department of Toxic Substances Control
Eco-SSL	Ecological Soil Screening Level
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESB	Ecotoxicological Screening Benchmark
ESV	Ecological Screening Value
HI	Hazard Index
HQ	Hazard Quotient
LOAEL	Lowest Observed Adverse Effect Level
MA	Merkel & Associates
MB	Mission Bay
MDL	Method Detection Limit
NDDB	Natural Diversity Database
NOAEL	No Observed Adverse Effect Level
OEHHA	Office of Environmental Health Hazard Assessment
PA	Phase I Predictive Assessment
PAH	Polynuclear Aromatic Hydrocarbons
PQL	Practical Quantitation Limit
PRG	Preliminary Remediation Goal
QA	Quality Assurance
QC	Quality Control
RA	Risk Assessment
SA	Scoping Assessment
SQL	Sample Quantitation Limit
SVOC	Semivolatile Organic Compounds
TPH	Total Petroleum Hydrocarbons
TRV	Toxicity Reference Value
UCLM	Upper Confidence Limit of the Mean
UF	Uncertainty Factor
USEPA	United States Environmental Protection Agency (in references)
U.S. EPA	United States Environmental Protection Agency (in text)
USFWS	United States Fish and Wildlife Service